Impacts of Water Level Fluctuations on Kokanee Reproduction in Flathead Lake

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IMPACTS OF WATER LEVEL FLUCTUATIONS ON KOKANEE REPRODUCTION IN FLATHEAD LAKE

Annual Progress Report FY 1984

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EXECUTIVE SUMMARY

This study was initiated in the fall of 1981 to delineate the extent of successful shoreline spawning of kokanee salmon in Flathead Lake and determine the impacts of the historic and present operations of Kerr and Hungry Horse dams. An investigation of the quantity and quality of groundwater and other factors affecting kokanee reproductive success in Flathead Lake began in the spring of 1982.

A total of 719 redds were counted in 17 shoreline areas of Flathead Lake in 1983 compared to 592 in 1981 and 1,029 in 1982. Shoreline spawning contributed three percent to the total kokanee spawning in the Flathead drainage in 1983.

Fifty-nine percent of the redds were located above 2883 ft, the operational minimum pool. The majority of those redds were constructed between 2885 and 2889 ft. In areas above minimum pool, intergravel dissolved oxygen concentrations were adequate for embryo survival and exhibited a decrease with depth. Limited data indicated apparent velocity may be the key in determining redd distribution.

Seventy-five percent of the redds located below minimum pool were constructed in a zone between 2869 and 2883 ft. In individual areas, apparent velocity measurements and intergravel dissolved oxygen concentrations were related to redd density. The variation in intergravel dissolved oxygen concentrations in the Yellow Bay spawning area was partially explained by lake stage fluctuation. As lake stage declined, groundwater apparent velocity increased which increased intergravel dissolved oxygen concentrations.

Mean survival to the eyed stage in the three areas below minimum pool was 43 percent. Prior to exposure by lake drawdown, mean survival to the eyed stage in spawning areas above minimum pool was 87 percent. This indicated habitat most conducive to successful embryo survival was in gravels above 2883 ft. prior to significant exposure. Survival in redds exposed to either extended periods of drawdown or to temperatures less than -10^{o}C was significantly reduced to a mean of 20-30 percent. Survival in individual spawning areas exposed by lake drawdown varied from 0 to 65 percent. Groundwater reaction to lake stage explained some of the variation in individual spawning area survival. Three types of groundwater reaction to lake stage were identified. Increased survival in exposed redds resulted from two of the three types. A significant statistical relationship was determined between embryo survival and the number of days exposed by lake drawdown.

The operation of Kerr Dam in 1983-84 was characterized by an early decline in lake stage, a longer period near minimum pool and a later and more rapid filling compared to the operation seen

in 1981-82 and 1982-83. Based on the survival relationship observed in natural redds exposed by drawdown in 1983-84, complete mortality from exposure would have occurred to all redds constructed above 2884.7 ft or 90 percent of all redds constructed above minimum pool.

Emergence traps placed over redds below minimum pool in Gravel, Blue, and Yellow bays captured fry in Gravel and Blue bays only. Duration of fry emergence in 1984 was three weeks longer than in 1982 or 1983, but was not related to the date of initial redd construction. Survival to fry emergence in Gravel Bay was calculated to be 28.9 percent of egg deposition or 57,484 fry. Survival to fry emergence above and below the zone of greatest redd density was 33.6 and 24.5 percent, respectively, indicating a relationship between survival and spawner site selection.

After analysis of the historic operation of Kerr Dam, it is believed that the dam has, and is continuing to have, a significant impact on successful shoreline spawning of kokanee salmon in Flathead Lake. Based on the evidence that prolonged exposure of salmonid embryo by dewatering causes significant mortality, the number of days the lake was held below various foot increments (2884 ft to 2888 ft) during the incubation period was investigated. The annual change in the number of days the lake was held below 2885 ft was further investigated because 80-90 percent of the redds constructed in spawning areas above minimum pool during this study were above this level. The operation since 1977 was found to be the least conducive to successful shoreline spawning since the earliest operation of the dam.

A significant relationship was established between female kokanee length, which is a measure of year class strength, and the number of days that lake levels were held below 2885 feet from 1966-1983. This relationship indicated that kokanee year class strength in Flathead Lake has been affected by the operations of Kerr Dam. The addition of lake level data improved the correlation in the Flathead River gauge height model, indicating kokanee year class strength has been affected by the operations of both Kerr and Hungry Horse dams.

ACKNOWLEDGEMENTS

Steve McMullin provided valuable supervision to this study prior to leaving the project manager's position in July, 1983. Pat Graham became more directly involved with the project after Steve's departure and maintained the necessary continuity for the remainder of the year. Rick Adams continued to provide invaluable assistance in office and field activities and his help is greatly appreciated. Terry Rolinger provided assistance to the project throughout the field season. Thanks are extended to Elinor Pulcini for her skills in data tabulation, graphics preparation and computer form design and data entry.

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INTRODUCTION

Kokanee salmon (Oncorhynchus nerka), the land-locked form of sockeye salmon, were originally introduced to Flathead Lake in 1916. By 1933, kokanee had become established in the lake and provided a popular summer trolling fishery as well as a fall snagging fishery in shoreline areas (Alvord 1975). Presently, Flathead Lake supports the second highest fishing pressure of any lake or reservoir in Montana (Montana Department of Fish and Game 1976). Kokanee salmon provided the largest fishery to Flathead Lake and the upper Flathead River (Robbins 1966, Hanzel 1977, Fredenberg and Graham 1982 and Graham and Fredenberg 1982). A creel census conducted in 1981-82 on the lake and upper drainage estimated 204,732 fisherman-days per year (Fredenberg and Graham 1982 and Graham and Fredenberg 1982). Kokanee represented 80 and 92 percent of the catch in the river and lake, respectively. Kokanee were captured by several angler methods including summer boat trolling, fall shoreline snagging and a localized winter hand-line fishery. Kokanee also provided forage for bull trout seasonally and year round for lake trout (Leathe and Graham 1982).

Kokanee salmon rear to maturity in Flathead Lake then return to various natal grounds to spawn. Spawning in the Flathead system usually occurs at the end of the fourth growing season. Kokanee are ubiquitous in their spawning habits using springs, lake outlet streams, larger rivers and lakeshore areas (Fraley and McMullin 1983 and Decker-Hess and McMullin 1983). Spawning in Flathead shoreline areas was first documented in the 1930's (Alvord 1975). Kokanee were seined from shoreline areas in 1933 and 21,000 cans of fish were processed and packed for distribution to the needy. Kokanee were first observed spawning in McDonald Creek in the 1930's and the Whitefish and Flathead rivers in the late 40's and early 50's (Stefanich 1953). Thirty shoreline spawning areas were also identified at this time. Because of a warming of winter water temperatures in the main Flathead River after the construction of Hungry Horse Dam on the South Fork Flathead River in the early 1950's, a substantial spawning run began to develop in the main river and below the dam. (Hanzel 1964 and Graham et al. 1980). Presently, kokanee are utilizing all of these areas mentioned as well as several streams in the Middle Fork Flathead River, the Middle Fork itself and the Swan River below Bigfork Dam.

The operation of Kerr Dam, located below Flathead Lake on the Flathead River, has altered seasonal fluctuations of Flathead Lake. Lake levels presently remain high during kokanee spawning in November and decline during the incubation and emergence periods. Groundwater plays an important role in embryo and fry survival in shoreline redds exposed by lake drawdown. Stefanich (1954) and Domrose (1968) found live eggs and fry only in shoreline spawning areas wetted by groundwater seeps. Recent studies have revealed that operation of Hungry Horse Dam severely impacted successful kokanee spawning and incubation in the

Flathead River above Flathead Lake (Graham et al. 1980, McMullin and Graham 1981, Fraley and Graham 1982, Fraley and McMullin 1983 and Fraley 1984). Flows from Hungry Horse Dam to enhance kokanee reproduction in the river system were voluntarily met by the Bureau of Reclamation in 1980 and 1981. Flows recommended by the Department of Fish, Wildlife and Parks in 1982 through the Northwest Power Planning Council have been provided by the Bureau and Bonneville Power Administration since 1982.

In lakeshore spawning areas in other Pacific Northwest systems, spawning habitat for kokanee and sockeye salmon was characterized by seepage or groundwater flow where suitable substrate composition existed (Foerster 1968). Spawning primarily occurred in shallower depths (<6m) where gravels were cleaned by wave action (Hassemer and Rieman 1979 and 1980, Stober et al. 1979a). Seasonal drawdown of reservoirs can adversely affect survival of incubating kokanee eggs and fry spawned in shallow shoreline areas. Jeppson (1955 and 1960) and Whitt (1957) estimated 10-75 percent kokanee egg loss in shoreline areas of Pend Oreille Lake, Idaho after regulation of the upper three meters occurred in 1952 by Albeni Falls Dam. After 20 years of operation, Bowler (1979) found Pend Oreille shoreline spawning to occur in fewer areas with generally lower numbers of adults. In studies on Priest Lake, Idaho, Bjornn (1957) attributed frozen eggs and stranded fry to winter fluctuations of the upper three meters of the lake. Eggs and fry frozen during winter drawdown accounted for a 90 percent loss of shoreline spawning kokanee in Donner Lake, California (Kimsey 1951). Stober et al. (1979a) determined irrigation drawdown of Banks Lake, Washington reduced shoreline survival during five of the seven years the system was studied.

The goal of this phase of the study is to evaluate and document effects of the operation of Kerr Dam on kokanee shoreline reproduction in Flathead Lake. Specific objectives to meet this goal are:

1) Delineate extent of successful shoreline spawning in Flathead Lake both above and below minimum pool and determine the impacts of the historical and present operation of Kerr and Hungry Horse dams.

2) Quantify and qualify influence of groundwater and other factors on reproductive success of spawners in Flathead Lake.

3) Determine the actual and potential contributions of shoreline spawning areas to the total kokanee population.

DESCRIPTION OF STUDY AREA

Flathead Lake is a large oligomesotrophic lake located in northwestern Montana (Stanford et al. 1981). It has the greatest surface area (476.6 km^2) of any natural freshwater lake west of the Mississippi River. The lake has a maximum length of 43.9 km and a maximum breadth of 24.9 km. Its mean depth is 32.5 m with a maximum depth of 113 m located near Yellow Bay (Potter 1978). The 199.1 km shoreline of the lake is characterized by numerous protected bays and inlets with gravel and cobble beaches. Approximately 50 percent of the shoreline substrate is composed of gravel and cobble (Figure 1). Sand and finer silts are generally restricted to the north and south end of the lake and compose 17 percent of the shoreline. The remaining 36 percent of the shoreline is characterized by steep cliffs and exposed bedrock.

Permanent and summer homes are found along the entire shoreline of Flathead Lake. Larger population centers are located at Polson, Somers, Lakeside and Bigfork. Moderating air temperatures, created by the buffering capacity of a large lake, have allowed successful cherry production on much of the land adjacent to the east shore. Agricultural production including cattle, sheep, grain and hay are restricted primarily to the southern and northern ends.

Kerr Dam, located 7 km downstream of the natural lake outlet, was closed in April, 1938. A license was issued to Rocky Mountain Power Company, a subsidiary to Montana Power Company (MPC) on May 23, 1930 (MPC 1976). The license was transferred to MPC on August 8, 1938 after the closing of the dam. The first generating unit of 56,000 kilowatts (KW) was placed into commercial operation on May 20, 1939. A second generating unit of the same capacity was installed and was placed into commercial operation in May, 1949. These two units utilized the natural flow of the Flathead River and the approximately 1,217,000 acre-feet of storage created in Flathead Lake by Kerr Dam. Following the filling of the Hungry Horse Reservoir in 1953, MPC installed a third 56,000 KW generating unit in December, 1954. A 1984 ruling by the Federal Energy Commission has determined ownership of the dam will be shared between MPC and the Confederated Salish and Kootenai Tribes.

Prior to impoundment by Kerr Dam, water levels for Flathead Lake remained relatively constant near 2882 ft from September to mid-April. Spring runoff increased the elevation to the maximum for the year (2893 ft) in May and June. Since impoundment, maximum lake elevation of 2893 ft has been reached in May and maintained into September. Drawdown usually begins in mid-September. Flood control and recreational constraints on the project require an elevation of 2883 ft be drafted by April 15, an elevation of 2890 ft be reached by May 30 and maximum pool level maintained

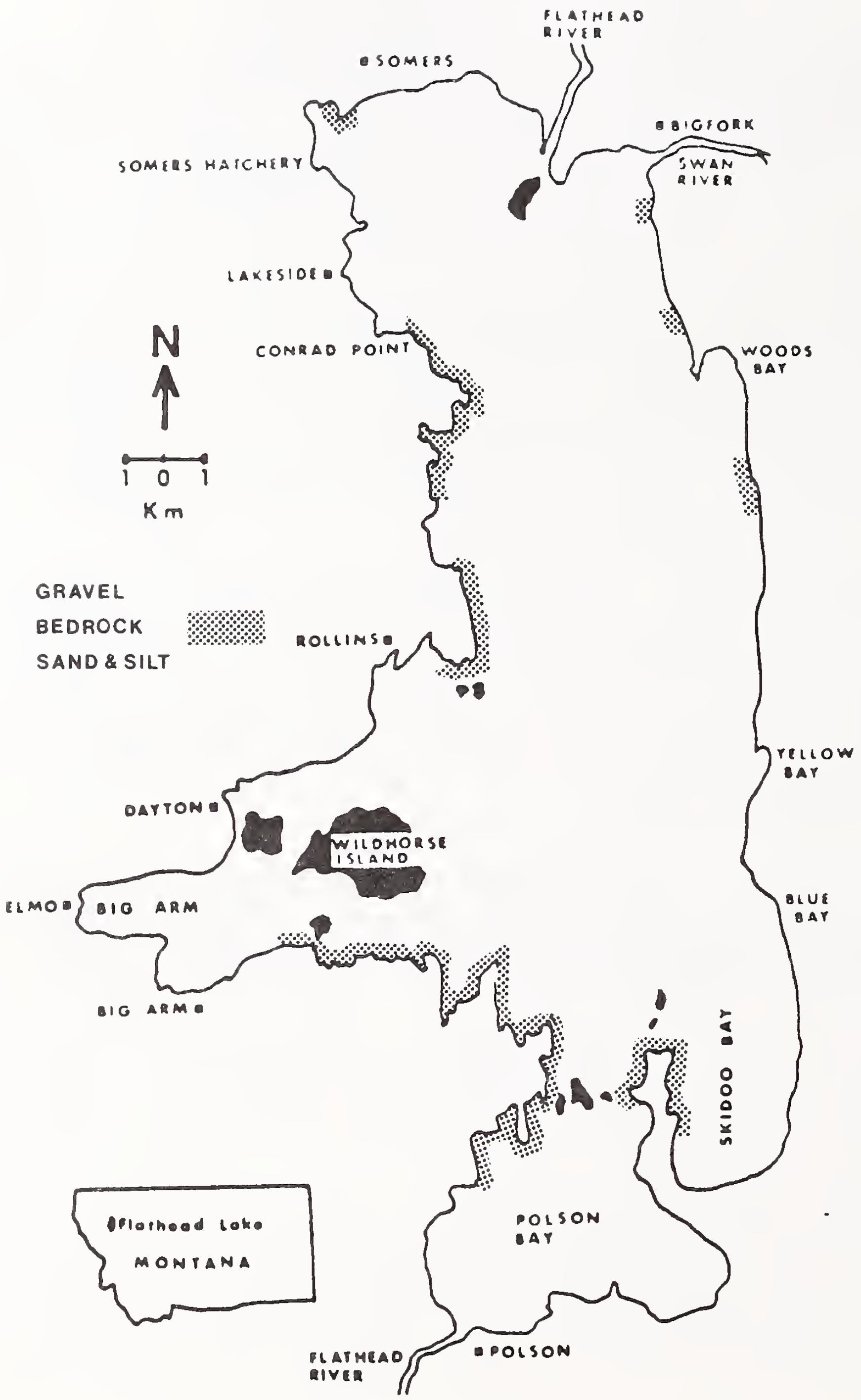

Figure 1. Map of Flathead Lake, including substrate composition of shoreline.

through Labor Day (Montana Power Company 1976). When the lake stage reaches 2886 ft during a flood, operation requires the gates be open and lake elevation not exceed 2893 ft. Natural channel restrictions allow a maximum outflow of 55,000 cfs when lake stage is 2893 ft but only an outflow of 5,200 cfs when lake stage is at minimum pool of 2883 ft (Graham et al. 1981).

Kerr Dam provides the bulk of MPC's system load frequency control. Loads are firm loads with interruptible loads being served from reserves. It provides 180,000 KW of peak capacity and 119,000 kw of critical period energy (MPC 1976). The system load typically has a winter peak (occurring generally in December and January) with a one-to-two hour peak during the evening hours ending at 6:00 or 7:00 p.m. During times of excess water, the dam is operated essentially for baseload. When the river is controllable, Kerr is used for both baseload (at a lower level) and peaking.

Two tributaries in the Flathead drainage, the South Fork of the Flathead River and Swan River, are presently regulated by hydroelectric facilities (Figure 2). The Swan River diversion at Bigfork was built in 1902 with a generating capacity of 4,150 KW (Graham et al. 1981). Hungry Horse Dam, located on the South Fork Flathead River, 8.5 km above its confluence with the main river, was closed in September, 1951. Hungry Horse has a capacity to generate 328,000 KW, regulating one-third of the drainage area to Flathead Lake. The electrical energy from the Hungry Horse project is marketed by the Bonneville Power Administration (BPA). The dam is operated primarily for flood control and hydroelectric energy production.

METHODS

KOKANEE SPAWNER SURVEY

Attention was focused on shoreline areas of Flathead Lake previously identified as kokanee spawning sites, groundwater upwellings or surface water inlets. Historic spawning areas documented in the 1950's by Stefanich (1953 and 1954) and Hanzel (pers. comm.) were monitored on a semi-weekly basis from October through December. Areas with groundwater potential or surface water inlets, but lacking verified kokanee spawning activity, were monitored less frequently, usually weekly or biweekly. A total of 90 km of shoreline was monitored during the fall of 1983.

Shoreline spawning activity was monitored by various methods beginning in mid-October. Initial sitings were made from the bow of a slow cruising boat or from a pram modified with a plexiglass viewing window (Decker-Hess and Graham 1982). After locating redds or mature kokanee in shoreline areas with the pram or jet

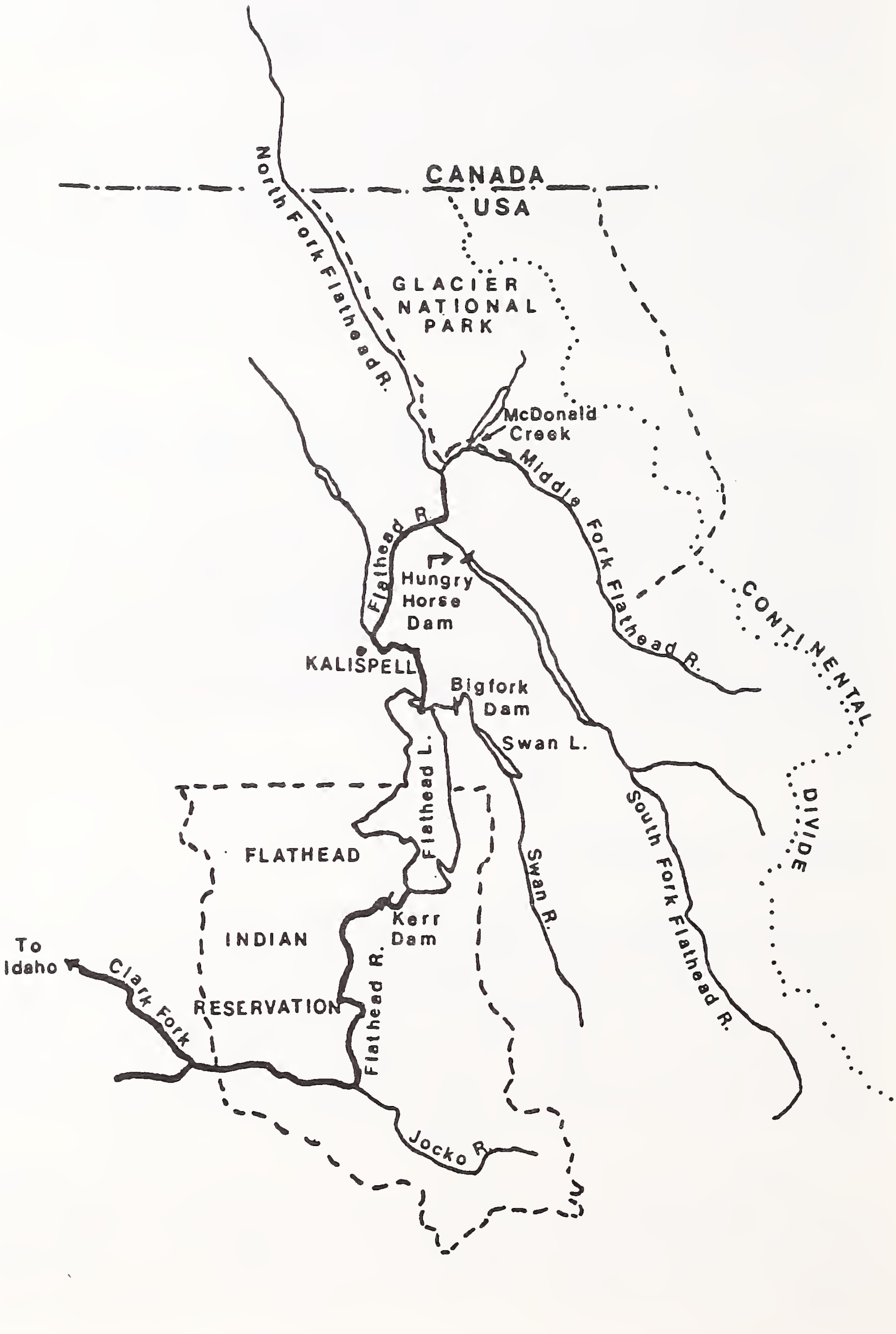

Figure 2. Map of Flathead drainage.

boat, the area was inventoried by SCUBA divers. Divers thoroughly investigated the spawning site horizontally and vertically counting redds and mature adults.

Floating gill nets and beach seines were used to collect adult kokanee from shoreline areas. Information on sex ratio, age composition and length (to the nearest mm) were obtained from the collected fish. Otoliths were collected for analysis of the age structure.

A spawner escapement estimate was accomplished in two spawning areas of Skidoo Bay. A technique utilizing weekly spawner counts and tag and recovery techniques designed to determine the average time individual fish remained in the spawning areas was used (McNeil 1964 and Lindsay and Lewis 1975). Data from spawner observations were plotted on a temporal basis. A summation of daily abundance was obtained by constructing an eye fitted curve of spawner counts and planimetrically determining the area under the curve in spawner-days (Pfeifer 1978). The number of spawner days was divided by the average time an individual fish remained in the area to arrive at an estimate of total escapement.

LAKE LEVEL FLUCTUATIONS AND AIR TEMPERATURES

Daily lake elevations were obtained from the USGS gauge station located on Flathead Lake at Polson. The Department of Commerce climatologic station at the University of Montana Yellow Bay Biologic Station collected the daily minimum air temperatures.

SPAWNING SITE INVENTORY AND MICROHABITAT

Spawning areas were mapped upon completion of major spawning activity. Because of the depth of most redds, SCUBA techniques were necessary to accurately chart the sites. To locate and record redds and spawning area boundaries, a metric fiberglass tape was stretched parallel to the shoreline for the length of the spawning area. Exact redd locations were determined by two measurements, distance horizontally on the parallel tape and distance out from the tape. Three transects, perpendicular to the shoreline and spaced horizontally to describe the entire spawning area, were used to collect microhabitat information from areas below minimum pool. In areas above minimum pool, points to collect microhabitat data were selected randomly where redds were dense and at individual redds where spawning was less dense. Intergravel dissolved oxygen and gravel samples for substrate composition analysis were collected at these points. To evaluate microhabitat changes during the incubation period, samples were collected from the same location immediately following spawning and again prior to emergence. Total spawning area and mean redd size were determined from field measurements.

Two to four substrate samples were collected during each sampling period. These samples were within the spawning area boundaries at all areas except Skidoo Bay IV. Depending on the depth of water, samples were collected with a shovel and grid and by SCUBA divers. Five to ten kg samples were placed in 19 liter plastic buckets for analysis (Shirazi and Seim 1979). Samples were dried and sieved through .063 mm, 2 mm, 6.35 mm, 16 mm, 50.6 mm and 76.2 mm mesh. Percent dry weight (accurate to 1 gm) was calculated for each sample. Deposition or scour of fine material as lake stage increased or decreased may reduce or enhance embryo survival and fry emergence from spawning areas above minimum pool. To monitor this potential effect, a substrate sample was taken from the Skidoo Bay Area I (Skidoo Bay East in 1982 and 1983) with each 0.3 m change in lake stage.

Various methods have been used to determine the effect of substrate composition on salmonid embryo survival and emergence. Embryo survival predicted from the substrate composition collected in shoreline spawning areas using cumulative distribution of sediment particle size and percent fines was compared with actual emergence estimates (Reiser and Bjornn 1979, and Irving and Bjornn 1984).

Intergravel dissolved oxygen samples were collected by a SCUBA diver using a hand operated rotary pump. (Decker-Hess and Graham 1982). A second diver on the surface used a floating discharge hose to collect samples in 325 ml B.O.D. bottles. To avoid contamination by lake water of the intergravel sample, yet to collect water from the egg depositional strata, all samples were taken 15.2 cm into the gravel. Samples were analyzed in the field using the modified Winkler method (Environmental Protection Agency 1974).

Groundwater Quality and Quantity

Several techniques were employed to measure groundwater stage and velocity in the study spawning areas. Seepage meters were used in areas when depth of water exceeded two meters (Lee and Cherry 1978). Instruments were placed along transects or in a horizontal or vertical pattern that described the spawning area. Water was collected from the meters on a monthly basis. Velocity in cm/hr, water quality and dissolved oxygen concentrations were determined. Seepage meters were also used to describe the groundwater system outside the spawning area boundaries. Four to five seepage meters were placed throughout the bay at a similar elevation and run bimonthly. Sandpoints were used to collect groundwater information in areas exposed by lake drawdown (Terhune 1958). One to five sandpoints were placed in each spawning area. Additional sandpoints were placed as lake levels receded. Groundwater stage data were collected on a weekly basis, dissolved oxygen concentration biweekly, water quality data monthly and gravel permeability data one time during the incubation period. Groundwater velocity was calculated from hydraulic conductivity

and gradient values (Woessner and Brick 1984). Collection of data occurred upon installation of the sandpoints through May. Continuous water level recorders registered groundwater stage in four meter deep wells in four spawning areas. The wells were placed .75-1 m above maximum pool to monitor groundwater stage level throughout the spawning, incubation and emergence periods. A complete discussion of methods can be found in Woessner and Brick (1983 and 1984).

EMBRYO SURVIVAL AND DEVELOPMENT

Embryo Survival

Kokanee embryo and alevin survival in shoreline areas were assessed by two methods. Natural redds were excavated at the eyed stage of development. Experimental egg bags were placed in various habitat types to supplement data gathered on natural spawned redds and to determine survival in habitat types not presently used. The bags were harvested on a monthly basis.

Redds were sampled in thirteen spawning areas to determine embryo survival during the 1983-84 field season. Fourteen percent of the counted redds were marked for excavation during the incubation period. Redds were excavated by various methods depending on the depth of water over the redd. Dry redds and redds affected only by groundwater were excavated using a shovel. Redds covered with less than one meter of water were sampled with a hydraulic sampling device similar to that designed by McNeil (1964) and modified by Fraley and McMullin (1983). In deeper redds, one hydraulic pump modified with a venturi suction device collected eggs and alevins which were manually agitated from the spawning gravels.

Green eggs were planted in four habitat types: 1) a groundwater area above minimum pool, 2) an area below minimum pool with similar microhabitat to an adjacent spawning area above minimum pool; 3) an area below minimum pool with the majority of substrate greater than 76.2 mm and 4) an historically used spawning area on the west shore. In each habitat type, horizontal lines each containing ten egg bags were spaced to thoroughly describe the plant area. Fifty eggs were placed in each fiberglass screen bag with gravel and stapled shut. Substrate composition, bottom elevation and apparent velocity were determined at each egg bag line once during the incubation period. Intergravel dissolved oxygen concentrations were determined immediately after the plant and each time the bags were harvested.

Embryo Development

Single probe and four probe thermographs were installed to record gravel temperatures at four spawning or egg plant areas. Intergravel temperatures were monitored throughout spawning and

incubation periods and temperature units for various stages of development were calculated. A four probe thermograph was placed in Skidoo Bay Area I, a spawning area above minimum pool, to monitor gravel temperature changes with lake drawdown. Probes were buried 15 cm in the gravel at bottom elevations of 2888 ft, 2886 ft, 2884 ft and 2883.3 ft. To monitor temperature differences both inside and outside the boundaries of a spawning area, a four probe thermograph was installed in Gravel Bay. Probes recorded lake temperature, intergravel temperature both inside (2881.3 ft) and outside (2882.4 ft) the spawning area and at an experimental egg plant adjacent to the spawning area (2887.8 ft). Single probe thermographs were placed at Station Creek in Dr. Richard's Bay at 2882.0 ft and at an experimental egg plant in Somers Bay at 2883.0 ft.

FRY EMERGENCE AND DISTRIBUTION

Natural Redds

In late March, deep water fry emergence traps designed by Stober et al. (1979a) were placed over marked redds in three east shore spawning areas. Information gathered from the traps included emergence timing, the effect of depth and density on fry quality and quantity and embryo survival to emergence. Traps were checked weekly and captured fry were preserved in ten percent formalin. No more than ten fry were kept from each trap during each sampling period. Fry were measured to the nearest 0.5 mm and weighed to the nearest 0.1 gram. Condition factors were determined for the sampled fry, $K = (W \times 10^5)/L^3$ (Carlander 1969).

Survival to fry emergence was calculated for the Gravel Bay spawning area. Data used for the calculation included number of redds constructed, mean fecundity, mean redd size, area covered by emergence traps and the mean number of fry captured per trap. The assumption was made that if the entire redd was covered by fry traps, 100 percent of the emerging fry from that redd would be captured. To test this assumption, three redds in Gravel Bay were completely covered with traps. It was assumed all fry emerging from those redds would be captured. The calculation used to determine percent survival from egg deposition to fry emergence was:

$$\text{percent survival to emergence} = \frac{(\text{\#traps needed to cover entire redd} \times \text{mean fry captured per trap}) \times \text{total number of redds}}{(\text{fecundity} \times \text{average number of females per redd}) \times \text{total number of redds}}$$

Experimental Embryo and Fry Studies

Artificial spawning channels at the Somers Fish Hatchery, Flathead Lake, were used in two experiments during the 1983-84

field season. A long-term study to monitor the effect of extended exposure on various stages of embryo development began in November. Five pairs of egg bags were planted in each of five channels and harvested after varying lengths of dewatering. Sediment levels of 20 percent fine material less than 6.35 mm were used in each channel to simulate conditions found in Skidoo Bay, a major spawning area above minimum pool. The experiment was completed in March.

The channels were used in a fry emergence experiment designed to determine the ability of fry to move laterally in groundwater through various substrate concentrations. The control channel, simulating a nongroundwater situation with water flowing over the substrate, contained 10 percent fines. The experimental channels contained 10, 20, 30 and 40 percent fines less than 6.35 mm. Two hundred sac fry were planted near the head of the control channel and one hundred sac fry were planted in each of the experimental channels.

RESULTS AND DISCUSSION

KOKANEE SPAWNER SURVEY

Adult kokanee were initially observed on 18 October in Dr. Richard's Bay North and Yellow Bay (Figure 3). Spawning continued through November with the last new redds counted on 5 December in Yellow and Blue bays (Appendix A Table 1). A single peak in spawning activity occurred on 10 November. Temporal distribution and spawner densities were similar to that found in 1981 when a single peak occurred in early November and the majority of spawning was completed by the first of December (Decker-Hess and Graham 1982).

Observations of spawning activity began when water temperatures declined between 10 and 10.6°C (50° - 51°F). Redd construction peaked when water temperatures were between 8.6 and 9.7°C (47.5 to 49.5°F). These temperatures fell within the range found by Hunter (1973) and Seeley and McCammon (1966) for kokanee spawning. These were well above initial threshold temperatures of 4.5°C considered by Bailey and Evans (1971) to be necessary for normal embryonic development. Temperatures at or below 4.5° were not recorded until one month after spawning. Temperatures at spawning were generally two degrees warmer than those recorded during 1982.

Shoreline spawning in 1983 contributed three percent to the total spawning in the Flathead drainage. Major spawning areas in 1983 were McDonald Creek (59 percent) and the Flathead River below the South Fork (27 percent) (Fraley 1984). Seventeen areas in eleven bays were utilized by spawning kokanee during 1983 in

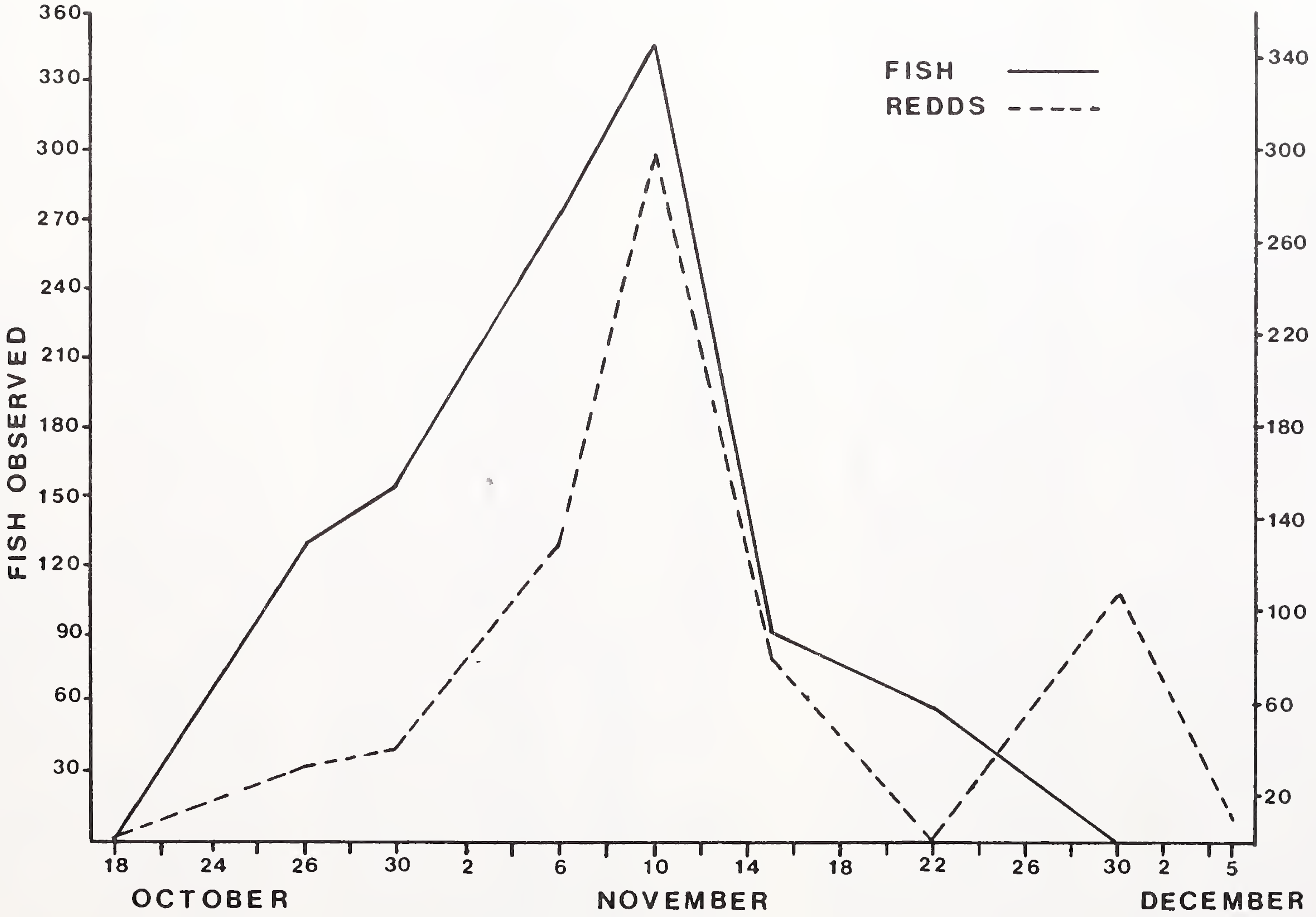

Figure 3. Temporal distribution of fish observed and new redds constructed in shoreline areas of Flathead Lake during the fall of 1983.

Flathead Lake (Figure 4). Nine bays were located on the east shore and two on the west shore. An area in Somers Bay not previously identified in this study was located in 1983. Two areas previously used by spawners in 1981 and 1982, a deep area in Woods Bay and an area above minimum pool at Pine Glen Resort, were not used during this spawning season.

A total of 719 redds were counted in the 17 shoreline areas. Redd concentrations ranged from 19 at Crescent Bay to 187 at Gravel Bay (Table 1). This total compared to 592 redds located in 1981 and 1,029 in 1982. Depth of water at the time of redd construction varied from .13 m at Skidoo Bay to 8.8 m at Gravel Bay. Redds constructed above minimum pool contributed 63, 50 and 59 percent of the total shoreline redds in 1981, 1982 and 1983, respectively. In other studies of regulated lakes and reservoirs in the Pacific Northwest, shallow water less than four meters have been found to be preferred habitat by shoreline spawning kokanee (Whitt 1957, Stober et al. 1979a and b, Hassemer and Rieman 1979 and 1980).

After three field seasons, the use of the glass bottom pram continued to be a reliable method for estimating trends in spawner abundance. During the three years of evaluation, observations from the glass bottom pram enumerated an average of 66 percent of the total redds located by SCUBA counts (Appendix A Table 2). Accuracy was found to increase with a decrease in water depth and redd densities. Pram counts were strongly correlated with SCUBA surveys ($r=.78$, $p\leq.001$, $n=29$). Because this method showed consistent results for three spawning seasons, it will be adopted as the method to estimate trends in spawner abundance for the remainder of the study.

Spawner Resident Time

Spawner escapement estimates calculated from redd counts and total spawner days divided by female resident time were nearly identical in Skidoo Bay Area I and II. Spawner escapement based on total fish days from 29 October to 22 November with a female residence time derived from this experiment of seven days was 261 (Appendix A Figure 1). The estimate using the final redd count of 110 multiplied by 2.4 fish per redd (Fraley 1984) was 264. In 1983, the final redd count in Skidoo Bay gave an accurate estimation of escapement in these two spawning areas.

Length and Age

Spawning kokanee were collected from nine shoreline areas for length information and age composition (Appendix A Table 3). The total length of female spawners for all age classes of 373 mm was similar to that found in 1982. The majority of the females in 1983 were Age III+. Age composition by area varied considerably. The 1978 year class dominated the female spawners at Yellow Bay in 1982 and 1983.

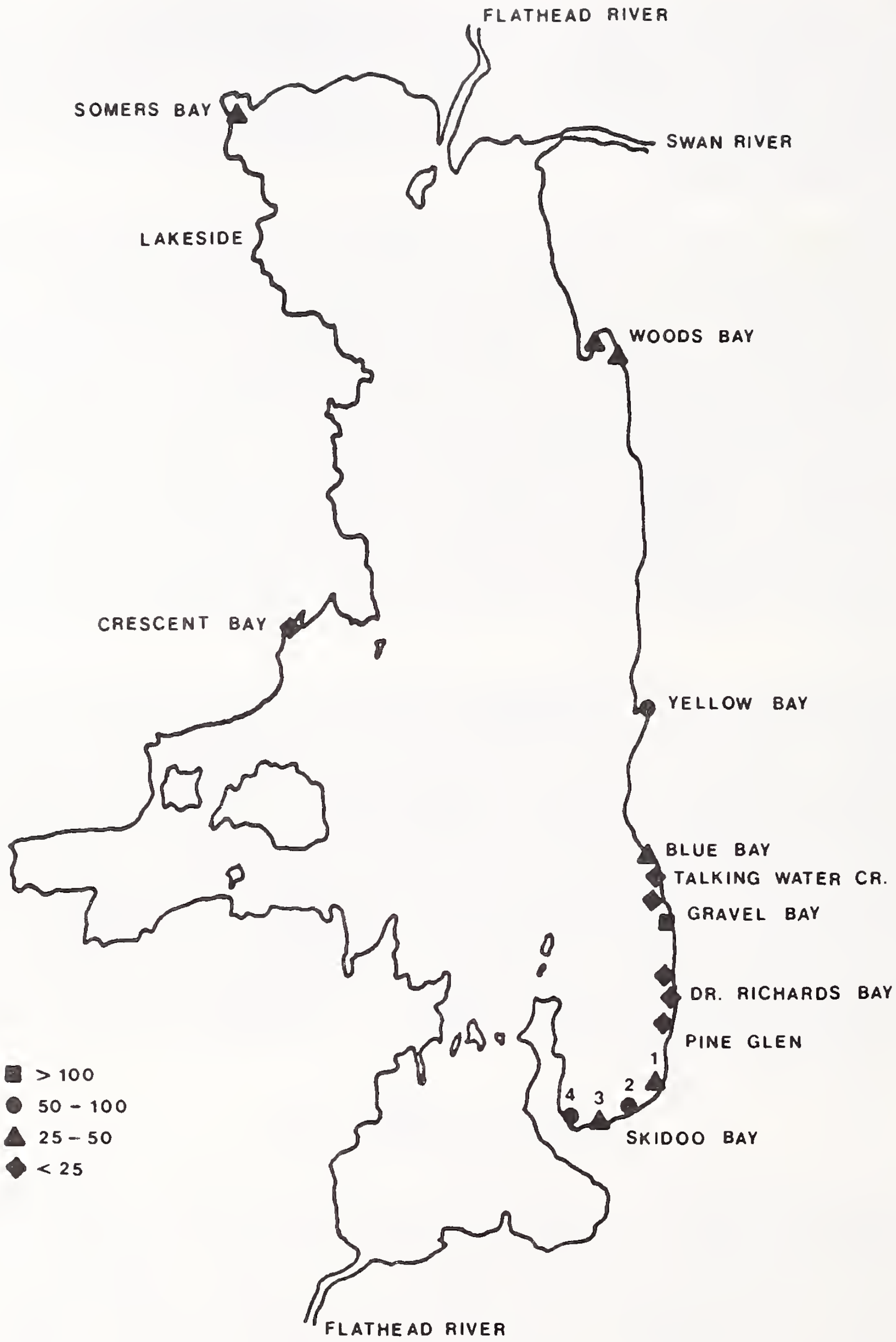

Figure 4. Location of shoreline spawning areas in Flathead Lake, 1983. Shape of symbol denotes number of redds in each area.

Table 1. Final SCUBA counts of kokanee redds by area and number above and below minimum pool in shoreline areas of Flathead Lake, 1983 (percent in parentheses).

Location	Total Count	Number Above Minimum Pool	Number Below Minimum Pool
Woods Bay			
East	30	30	0
West	46	34	12
Yellow Bay			
Major	67	3	64
Flume/Other	12	12	0
Blue Bay	45	0	45
Talking Water Creek	33	33	0
Gravel Bay	187	15	172
Dr. Richard's Bay			
North	23	23	0
South	17	17	0
Boat Launch	12	12	0
Skidoo Bay			
I	43	43	0
II	66	66	0
III	41	41	0
IV	50	50	0
Crescent Bay	19	19	0
Somers Bay	28	28	0
TOTAL	719	426 (59%)	293 (41%)

Mean length of adult male kokanee was 389 mm, 16 mm larger than the females. Eighteen percent of the 1983 males were Age IV+ compared to 40 percent in 1982. Nearly half of the males collected at Somers and Hatchery bays were Age II+. Hanzel (1984) indicated hatchery stock was generally younger than the natural stock in a spawning population.

The age and length of spawners varied between the nine shoreline areas sampled. Overall length was found to be a function of age composition (Hanzel 1984). A greater percentage of younger fish in the spawning population decreased overall size.

LAKE LEVEL FLUCTUATIONS AND AIR TEMPERATURES

Flathead Lake level fluctuations during November through May of 1983-84 were characterized by an early decline in lake stage, a longer period near minimum pool and a later and more rapid filling compared to the operation seen in 1981-82 and 1982-83 (Figure 5). A major difference in fluctuation occurred in November when lake stage dropped 2.7 ft. This compares to 1.8 ft and 2.0 ft in 1982 and 1981, respectively. The majority of the November decline occurred after the peak in spawning activity. Minimum pool of 2883.80 ft was reached on 6 April, nearly one month later than the two previous years. Lake levels were held at or below 2885 ft (eight feet below maximum pool) for a three month period. Because of a late and light spring runoff, lake stage did not begin to increase until 12 May. This compared to mid-April in 1982 and 1983. Lake stage increased over two feet during the week of 13 May.

Minimum daily air temperature at the climatological station at Yellow Bay dipped below the critical level of -10°C (Fraley and Graham 1982) for a two week period from 16 to 31 December and again for an eight day period from 14 to 21 January. All redds constructed above 2887.4 ft and 2886.0 ft were exposed during the first and second cold periods, respectively. Over 50 percent of the redds built above minimum pool were above 2887.4 ft and nearly 70 percent were above 2886.0 ft. The effect of these cold temperatures to sampled embryo survival will be discussed later in the report.

SPAWNING SITE INVENTORY AND MICROHABITAT

Parameters important to spawning site selection and successful embryo survival included intergravel dissolved oxygen, groundwater apparent velocity, substrate composition and gravel temperatures. Information to define these parameters was collected at spawning areas in Yellow, Woods, Skidoo, Somers, Crescent and Gravel bays and to a limited extent at Blue and Dr. Richard's bays.

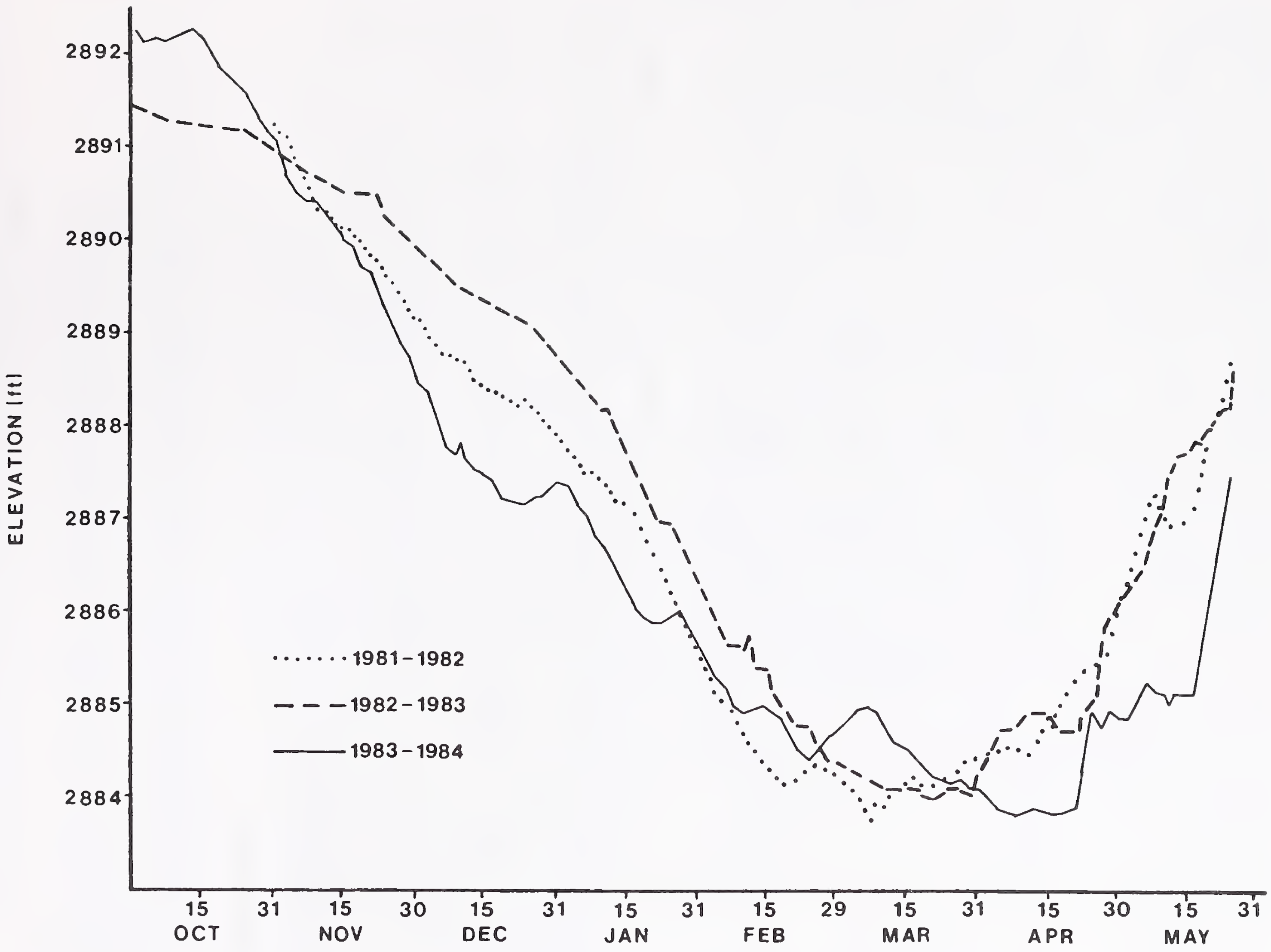

Figure 5. Flathead Lake levels in feet from 15 October to 31 May for 1981-82, 1982-83 and 1983-84.

Spawning Areas Above Minimum Pool

Redd Distribution

Three hundred redds were located above minimum pool in nine shoreline study areas during 1983. Redds were distributed between bottom elevations of 2881.9 to 2890.1 ft. Preferred habitat was located between 2885 to 2889 ft where 83 percent of the redds above minimum pool were constructed (Figure 6). Vertical distribution for individual areas is located in Appendix A Figure 2.

The number of redds located at each study area above minimum pool varied from 19 at Crescent Bay to 68 at Skidoo Bay Area II (Skidoo Bay West in 1982). Total spawning area at each of the four sites in Skidoo Bay was similar, ranging from 215 m^2 at Area Number I to 293 m^2 at Area II. The percent of the total area covered by redds was also similar with a range of 34 to 45 percent. When comparing area dimension and redd density data from 1981-83 at Area I, several trends were apparent (Appendix A Figure 3). The range of redd depth was not density dependent, but the size of the spawning area and the percent of the area used was directly related to the number of redds. Although the majority of the redds in the three years were located between 2885-89 ft, the distribution by foot zone varied from year to year.

Redd counts at Dr. Richard's Bay North for 1981, 1982 and 1983 were 106, 45 and 23, respectively. Spawning area size and specifically the northern portion of the area declined directly with redd numbers. No redds were located in the northern portion of the area or below 2886 ft during 1983 when densities were at their lowest. Apparent velocity measurements varied considerably between the north and south portions of the area. Mean apparent velocities in the southern portion of the spawning area ranged from .08-1.16 cm/hr where redd densities were highest and 2.96-9.9 cm/hr where densities were lowest (Woessner and Brick 1984). This indicated there may be a maximum velocity spawning kokanee are sensitive to.

Microhabitat

The critical value for dissolved oxygen for development and survival of salmonid embryos varies with the stage of development. A value greater than 6.5 mg/l has been determined by various authors to be critical during hatching and will be used as the minimum value for embryo survival in shoreline areas.

At the time of spawning, intergravel dissolved oxygen concentrations in spawning areas above minimum pool were above 7.8 mg/l at 86 percent of the 59 stations sampled (Appendix A Table 4). Intergravel oxygen concentrations were less than 6.5 mg/l at 33 and 100 percent of the sampling stations at Skidoo Bay Area III + IV, respectively. Apparent velocity measurements at these two areas were one to four times lower than the two eastern spawning

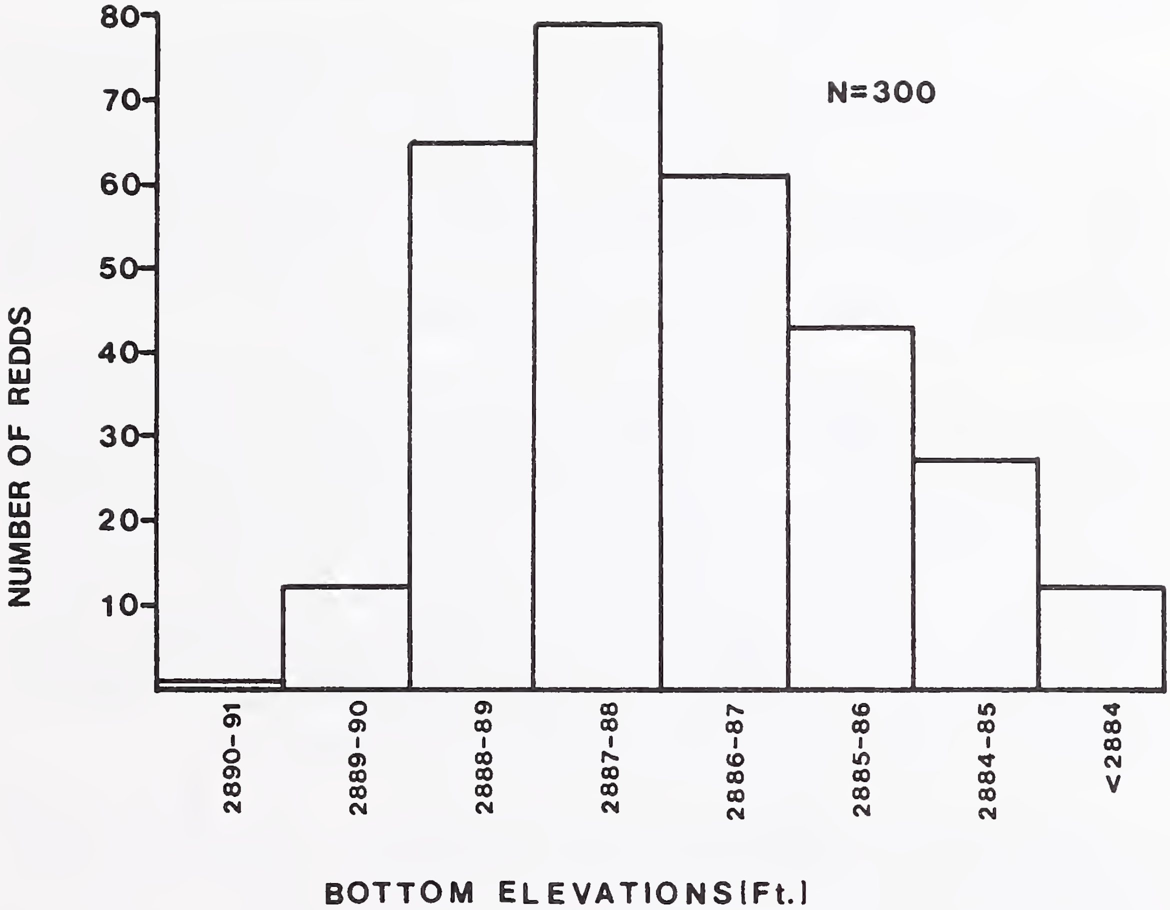

Figure 6. Vertical distribution of redds by bottom elevation in foot intervals for spawning areas above minimum pool in Flathead Lake, 1983.

areas in Skidoo Bay (Woessner and Brick 1984). Intergravel oxygen concentrations from all areas did exhibit a general trend of decreasing with an increase in depth. There was no significant difference in oxygen concentrations above or below 2885.0 ft, however, to explain the distribution of redds. Because of a decline in groundwater stage with lake stage at most areas above minimum pool, a second series of samples was not completed in March. Of the 14 samples collected, oxygen concentrations were greater than 6.8 mg/l.

Prior to the spawning period in August and September, apparent velocity was measured at 2887.4 ft, 2884.3 ft and 2883.9 ft in Skidoo Bay Area I and at the lower two sites in October (Woessner and Brick 1984). Although only a trend could be suggested from these limited data, groundwater velocities decreased with depth with an eight fold difference above and below 2885 ft. These data indicate apparent velocity may be a key in determining redd distribution in spawning areas above minimum pool.

Four substrate samples were taken at each spawning area above minimum pool. Samples were taken at 2885 and 2887 ft, once during spawning and again at incubation (Appendix A Table 5). Fine material (less than 6.35 mm) contributed from 0.6 to 40.8 percent of the substrate composition and was lowest at Woods Bay East and highest at Crescent Bay. There was a temporal increase in percent fine materials from spawning to incubation at six of the nine areas. The increase ranged from 6.3 percent at Skidoo Bay Area I to 269 percent at Somers Bay. The two areas most exposed to prevailing winds, Crescent and Dr. Richard's bays, showed a decrease in fine material from spawning to incubation.

To determine percentage of fines reaction to lake stage change at Skidoo Bay from spawning through emergence, a substrate sample was taken at 2885.0 ft with every .3 m change in lake elevation. A steady increase in fine material was observed through lake stage decline and early refill. As lake levels receded, fine material was deposited that could not be flushed from the system by wave action. The accumulated fine material returned to percent composition recorded at spawning after the lake was at maximum pool for two months. Fines were still near 20 percent during the fry emergence period in March and April, which could inhibit lateral movement of fry through the gravels.

Spawning Areas Below Minimum Pool

Redd Distribution

Three study areas below minimum pool, Gravel, Yellow and Blue bays, were the site of 300 redds during 1983. Redd elevations varied from 2853.4 to 2885.0 ft. Redds were not randomly distributed within the range of depth used (Figure 7). Seventy-

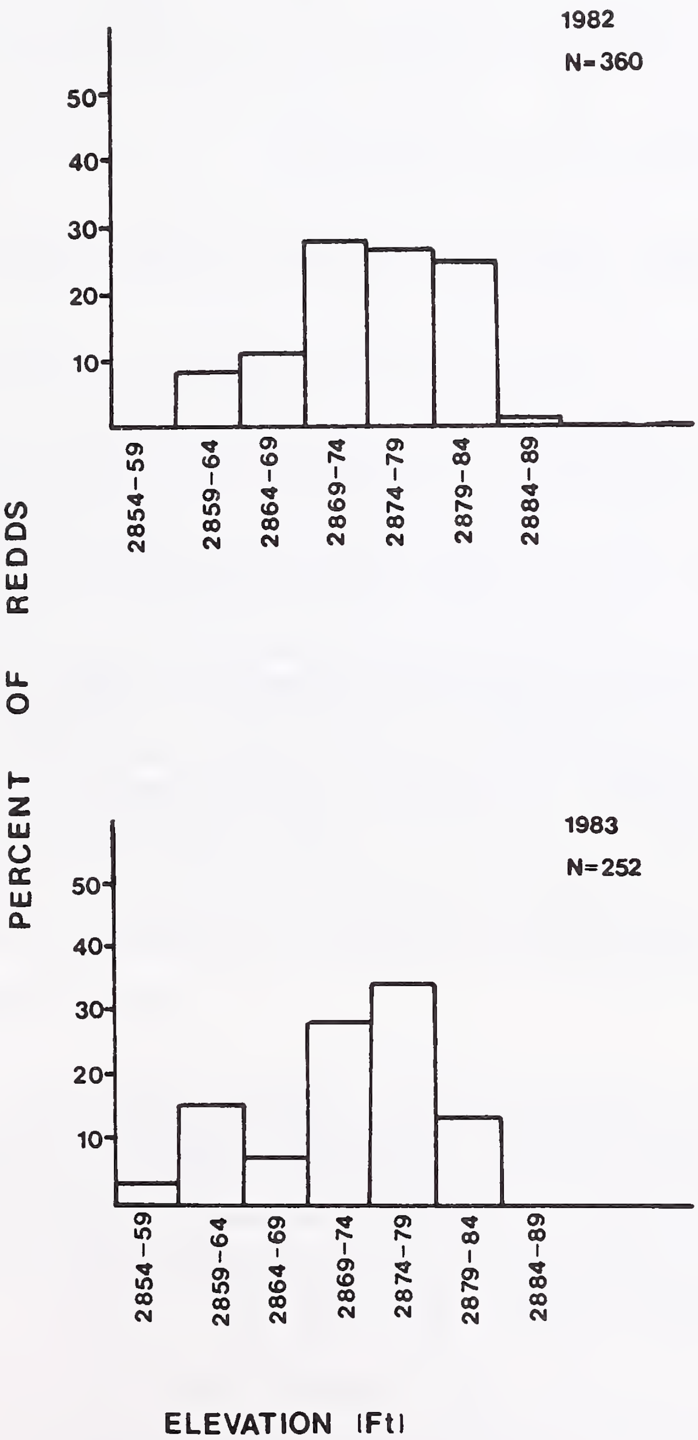

Figure 7. Vertical distribution of redds by bottom elevation in five foot intervals at Gravel and Yellow Bays for 1982 and 1983.

five percent of the redds were located in a 15 foot zone between 2869-2884 ft. In 1982, eighty percent of the counted redds were distributed similarly (Decker-Hess and McMullin 1983).

Redd distribution may be partially explained by groundwater apparent velocity. At Yellow Bay, apparent velocities were significantly different above and below the zone of greatest redd density in 1982 and 1983 (Woessner and Brick 1984). No significant differences in apparent velocities above and below 2869 ft at Gravel Bay occurred during the spawning period in 1982 or 1983 (Woessner and Brick 1984). During incubation, however, velocities decreased with distance from the shore.

Although the size of the Gravel Bay spawning area increased with redd numbers from 1982 to 1983, the relationship was not direct. Fifteen percent fewer redds were constructed in 1983 but area size decreased by only seven percent. Location and the boundaries of the area were nearly identical for the two years (Appendix A Figure 4). Redd density was highest on the western end of the area for both years. Groundwater apparent velocities were lower in the western area compared to the center and eastern portion of the area in 1982, but a similar trend did not occur in 1983 (Woessner and Brick 1984). These data indicate there may be a maximum velocity suitable for kokanee spawning habitat.

Although spawning area size increased with an increase in redd numbers at Yellow Bay, there was no direct relationship in the three years of study (Appendix A Figure 5). A larger number of redds were located at shallower depths (above 2879 ft) when densities were highest. A 400-600 percent increase in redds above 2884 ft was observed in 1982 (168 total redds) when compared to 1981 and 1983. This expansion into shallower waters in 1982 also accounted for a dramatic increase in area size. Considerable overlap in the area used by spawners in all three years occurred at depths below 2884 ft.

Microhabitat

Intergravel dissolved oxygen concentrations were collected from the spawning areas at Gravel and Yellow bays (Appendix A Table 4). Concentrations in Gravel Bay were similar between the spawning and incubation period and between 1982-83 and 1983-84 (Decker-Hess and McMullin 1983). Concentrations were above 6.5 mg/l at all stations except for the deepest sample from each of the three transcets (2862.2 - 2872 ft).

Intergravel dissolved oxygen samples were collected from 16 stations along three transects in the Yellow Bay spawning area (Appendix A Table 4). Immediately following spawning, intergravel dissolved oxygen was less than 6.5 mg/l at 62 percent of the sampling locations. By March, only one third of the sampling stations were less than 6.5 mg/l. Intergravel dissolved oxygen concentrations demonstrated a similar temporal fluctuation pattern

in 1982-83 (Decker-Hess and McMullin 1983). The temporal fluctuation can be partially explained by the relationship between groundwater apparent velocities and lake stage fluctuation (Woessner and Brick 1984). As lake stage declined in the fall, groundwater discharge increased causing greater velocities in the lake substrate. This increase in groundwater velocities increased intergravel dissolved oxygen concentrations. A significant relationship existed between the number of intergravel dissolved oxygen samples with concentrations less than 6.5 mg/l and lake stage during the spawning and incubation period ($r=.9699$, $p\leq.001$).

Substrate composition was suitable for successful embryo survival at the three study areas below minimum pool. Percent fines were below 20 percent at all sampling sites with the exclusion of the western sample in Yellow Bay (Appendix A Table 5).

EMBRYO SURVIVAL AND DEVELOPMENT

The intergravel environment of salmonid spawning areas is seldom conducive to high survival of incubating embryos. Royce (1959), Johnson (1965) and Koski (1966) reported survival to emergence ranging from 1 to 30 percent for various salmonid species in unaltered spawning environs. McNeil (1968) determined that incubation mortality was the most important factor governing year class strength of pink salmon in southeast Alaska streams. Stober et al. (1978) obtained similar results with sockeye salmon in the Cedar River, Washington. With naturally occurring mortality of this magnitude, negative impacts from man-induced changes in the physio-chemical environment of the spawning site can be the determining factor in the complete loss of a year class.

Spawning Areas Above Minimum Pool

Natural Redd Sampling

January

Redds were sampled in eight spawning areas above minimum pool in late January and early February to determine embryo survival to the eyed stage. Lake stage at the time of sampling was between 2885 to 2886 ft. Fifteen percent of the constructed redds above minimum pool were sampled. Redds in Dr. Richard's Bay North could not be sampled due to removal of the marking stake by ice formation. Survival information at individual redds are on file at the Department of Fish, Wildlife and Parks in Kalispell, Montana.

Prior to drawdown exposure, habitat most conducive to kokanee embryo survival was found in gravels above minimum pool (2883.5 ft) (Appendix B, Table 1). Mean survival to the eyed stage above minimum pool was 87 percent compared to 43 percent below minimum pool. A similar trend was found during the 1982-83 incubation

period (Decker-Hess and McMullin 1983). Mean survival in redds constructed in the zone of highest redd density above minimum pool was greater than redds outside the zone. Mean survival in redds within the highest redd density zone was 83 percent compared to 73 percent outside this zone. The difference was not statistically significant.

Temperatures below the critical level of $-10^{\circ}C$ occurred for fifteen days in December and again for seven days in January. After an average of 20 days of exposure to $-10^{\circ}C$ air temperatures, mean survival was 24.2 ($\pm$ 18) percent, ($p \leq .05$) (Appendix B Table 2). Mean percent survival ranged from zero at Crescent and Somers bays and Skidoo Bay Area I to 99% at Skidoo Bay Area II. The significantly higher survival found in exposed redds at Skidoo Bay Area II was believed to be a result of greater groundwater apparent velocities in the exposed gravels (Woessner and Brick 1984). Mean apparent velocity values of 3.03 cm/hr at 2886.0 ft in Skidoo Bay Area II were three times higher than those found in any other exposed spawning area during the incubation period.

Based on known redd distribution, 70 percent of the redds constructed above minimum pool would have been impacted by exposure to temperatures less than $-10^{\circ}C$ during the 1983-84 incubation period. The significant adverse effects of ambient air temperatures at freezing and below on salmon embryo survival have been documented by various authors (Kimsey 1951, McNeil 1967, McMullin and Graham 1981 and Fraley and Graham 1982).

In summary, greatest embryonic survival was found above minimum pool prior to lake drawdown in January. Redd site selection was related to embryonic survival although the relationship was not significant. Survival was reduced from 87 percent to 24 percent after redds were exposed to 20 days of air temperatures less than $-10^{\circ}C$.

March

Sixty percent of the redds sampled in early March had been previously sampled in late January and early February. When the majority of the eggs examined in an excavated redd in January were live and eyed, a sample of eggs were collected for analysis with the remainder being reburied and sampled again at a later date. This allowed a redd with a known survival to be monitored as length of exposure by drawdown increased.

Lake stage at the time of sampling was 2884 ft. In January, mean survival in the 18 redds sampled was 87 percent with an average of 4 days exposure by lake drawdown. None of these redds had been exposed to ambient air temperatures less than $-10^{\circ}C$. By March, mean survival was reduced to 31 percent after an average of 51 days of exposure (Appendix B Table 3). Complete mortality occurred in 60 percent of the redds sampled. Area survival ranged from 0 at Woods Bay East to 65 percent at Skidoo Bay Area I.

Development in redds during the second sampling ranged from 100 percent uneyed to 100 percent yolk sac resorption with a mean of 63 percent hatch. Based on predicted development from thermograph records at Skidoo Bay and normal development data from the literature, embryos unaffected by drawdown exposure should have completed yolk sac absorption by 1 March (Figure 8). Development was delayed with an increase in exposure because of a cooling in gravel temperatures.

Increased exposure from 20 to 51 days caused survival in redds above minimum pool to be reduced from 87 to 31 percent. Development was also delayed as a result of lake drawdown exposure.

Groundwater and Embryo Survival

The effect of groundwater velocity and distribution is an obvious key in extending survival in exposed redds. Groundwater data collected during 1982-83 and 1983-84 indicated an additional 12 m of vertical shoreline can be wetted depending on the groundwater system present (Decker-Hess and McMullin 1983 and Woessner and Brick 1984).

In general, three types of groundwater reaction to lake stage fluctuation were identified in Flathead Lake during the 1983-84 field season. These were: Type I: The water table reacted instantaneously with lake stage fluctuation (Figure 9), Type II: The water table showed a lag behind lake stage fluctuation (Figure 10), and Type III: The water table acted independently of lake stage (Figure 11). A total of 108, 109, and 137 redds above minimum pool were counted in Type I, II, and III areas, respectively (Table 2).

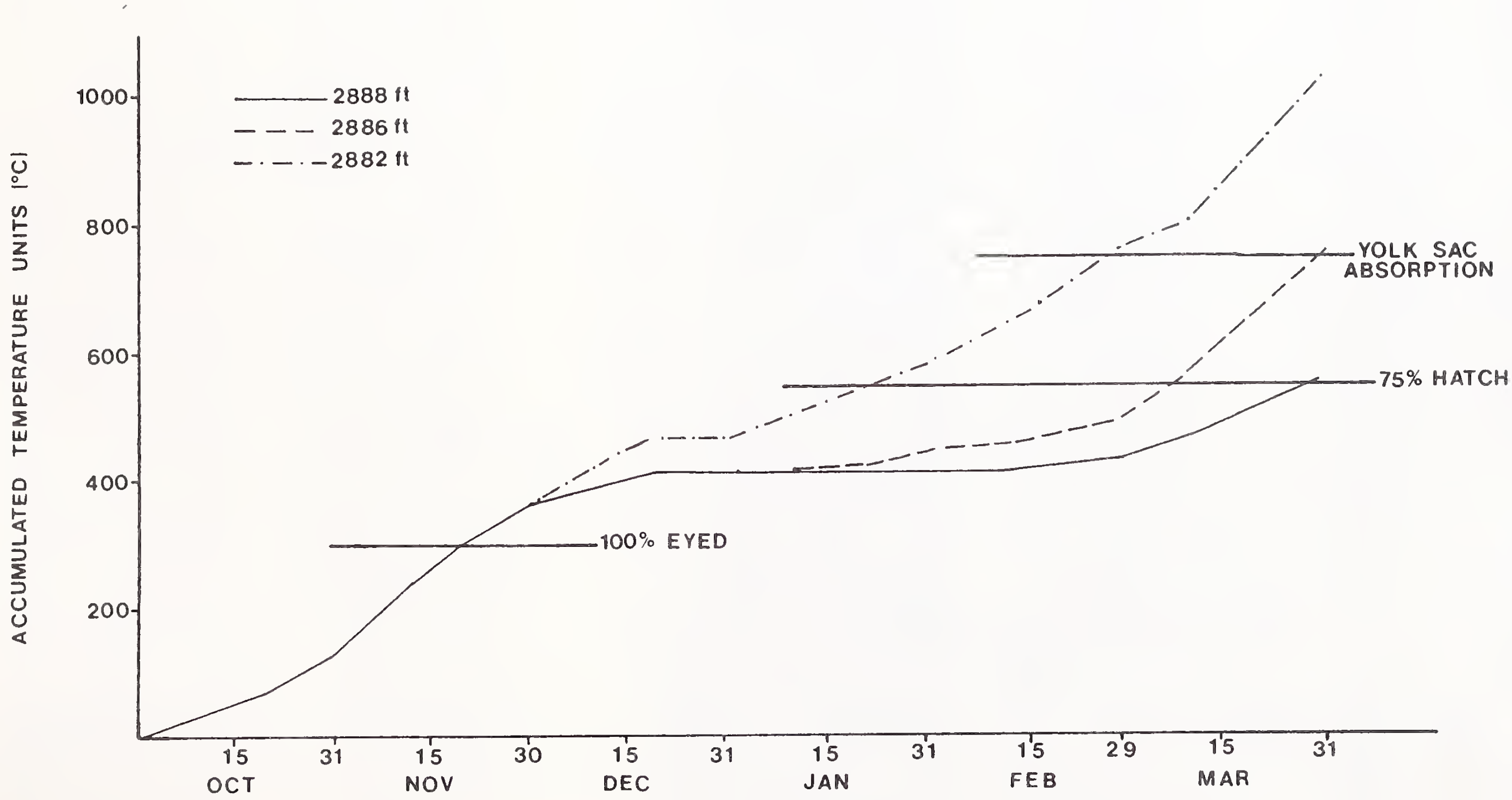

Figure 8. Accumulated temperature units from three gravel zones at Skidoo Bay spawning area I from 1 October, 1983 to 1 April, 1984. Various stages of development denoted by horizontal lines.

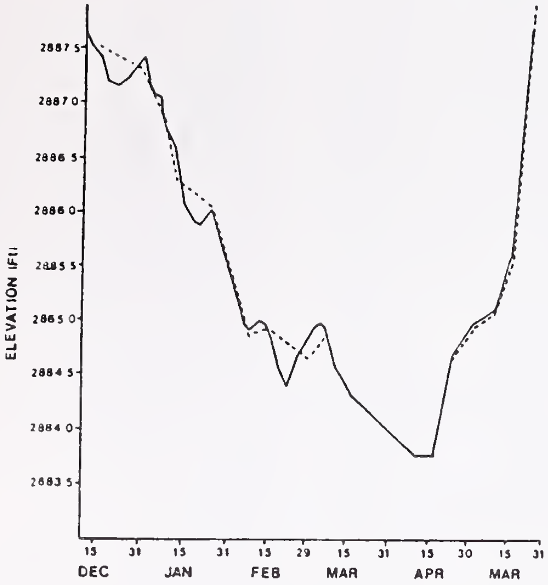

Figure 9 Comparison of lake level fluctuations (solid line) and water table fluctuations (dotted line) at Woods Bay West, an example of type 1 groundwater areas. Stars denote the period of time that the well was dry.

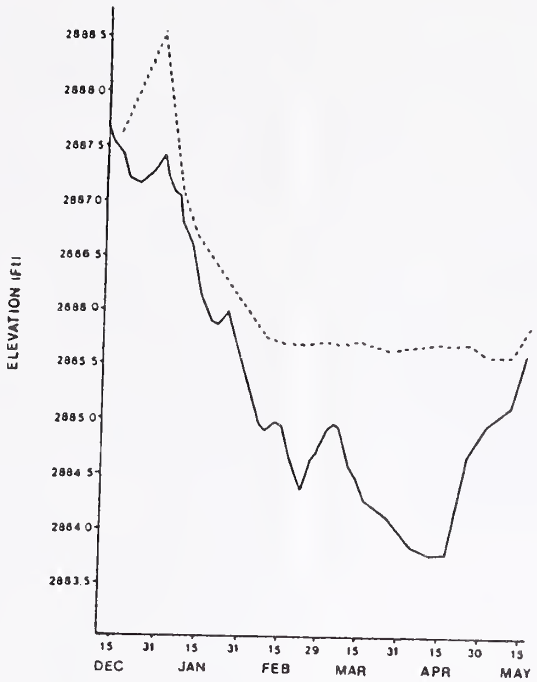

Figure 10 Comparison of lake level fluctuations (solid line) and water table fluctuations (dotted line) at Yellow Bay, an example of type 2 groundwater areas.

Figure 11 Comparison of lake level fluctuations (solid line) and water table fluctuations (dotted line) at Dr. Richard's Bay North, an example of type 3 groundwater areas.

Table 2. Categories of groundwater reaction to lake stage fluctuation at shoreline spawning areas and the number of redds above 2884.0 ft at each of those areas.

Type I	Woods Bay West	35
	Woods Bay East	30
	Dr. Richard's Bay South	16
	Somers Bay	27
		108
Type II	Skidoo Bay I (East)	43
	Skidoo Bay II (West)	66
		109
Type III	Dr. Richard's Bay North	23
	Skidoo Bay III	41
	Skidoo Bay IV	50
	Crescent Bay	23
		137

These groundwater systems may have varying effects on the survival potential of kokanee embryos. In Type I areas groundwater table adjusted instantaneously to lake stage affording no additional protection to the developing embryos from dessication and freezing. By the second redd sampling in March, the two areas showing the lowest survival were Woods Bay East and West, both Type I areas. In Type II areas, groundwater level ranged from .04 to 1.1 vertical meters higher than lake stage. The difference between groundwater and lake elevation could potentially enhance kokanee embryo survival in redds exposed by lake drawdown. In Skidoo Bay Areas I and II, Type II areas, survival to the eyed stage at the second sampling was 65 and 24 percent, respectively. In Type III areas, where groundwater acted independently of lake stage, development may proceed uninhibited provided groundwater flow is within an acceptable range. At Skidoo Bay Area IV, groundwater remained 1.5 meters higher than lake stage. Survival was 74 percent to the second sampling in this area, a Type III area.

In summary, kokanee embryo survival during the incubation period may be enhanced by groundwater flows depending on the system present. Lake elevation, however, would have to be increased to allow successful emergence from redds wetted by groundwater only. If lake elevations were not increased by the

time of emergence, fry movement would have to occur laterally through the gravel. Success of lateral gravel movement by fry is not presently known.

Embryo Survival and Drawdown Exposure

A significant statistical relationship between embryo survival and exposure by lake drawdown was documented in 1983-84 using natural redd data and experimental egg plants. Because the experimental egg bags were harvested on a monthly basis and the number of days exposed and stage of development at the time of sampling could be controlled, the relationship could be more accurately determined.

All redds and egg plants with development greater than 50 percent hatching at the time of sampling were eliminated from the analysis. The greater sensitively of alevins to exposure has been documented in the literature (Hawke 1978, Stober et al. 1979a, Reiser and White 1981a, Becker et al. 1982) but this relationship had not been quantified in the Flathead system. Prior to dewatering, survival to the alevin stage in channel #2 at the Somers Hatchery was 98 percent. Following hatching, the water was shut off and sampled daily. After 24 hours of dewatering, survival had been reduced to 59.5 percent. After 48 hours, complete mortality had occurred. Because of this increased sensitivity of alevins to dewatering, the relationship only included embryos developed to the eyed stage.

Embryonic survival in experimental plants in Skidoo Bay and the hatchery channels was negatively correlated to length of exposure ($r=-.9503$, $p<.0001$, $n=20$) (Figure 12). Based on this relationship, complete mortality would occur after 52 days of exposure. Comparing this correlation to a similar relationship documented by egg bag data in 1982-83, complete mortality did not occur until 78 days of exposure. The earlier mortality predicted in 1983-84 probably resulted from the effect of air temperatures less than $-10^{\circ}C$ on decreasing embryo survival. No temperatures less than $-10^{\circ}C$ were recorded in 1982-83. Comparing groundwater data for the two years, increased length of wetness by groundwater was not a factor in the increased mortality observed in 1983-84 (Decker-Hess and McMullin 1983 and Woessner and Brick 1983 and 1984).

Data collected from naturally spawned redds were correlated with number of days of exposure by lake drawndown. This relationship was also significant and embryo survival was again negatively correlated to number of days of exposure ($r = -.6389$, $p<.0001$, $n=42$). Complete mortality based on the relationship derived from natural redd sampling would occur after 98 days, compared to a predicted 52 days from the experimental egg plants. Again, the

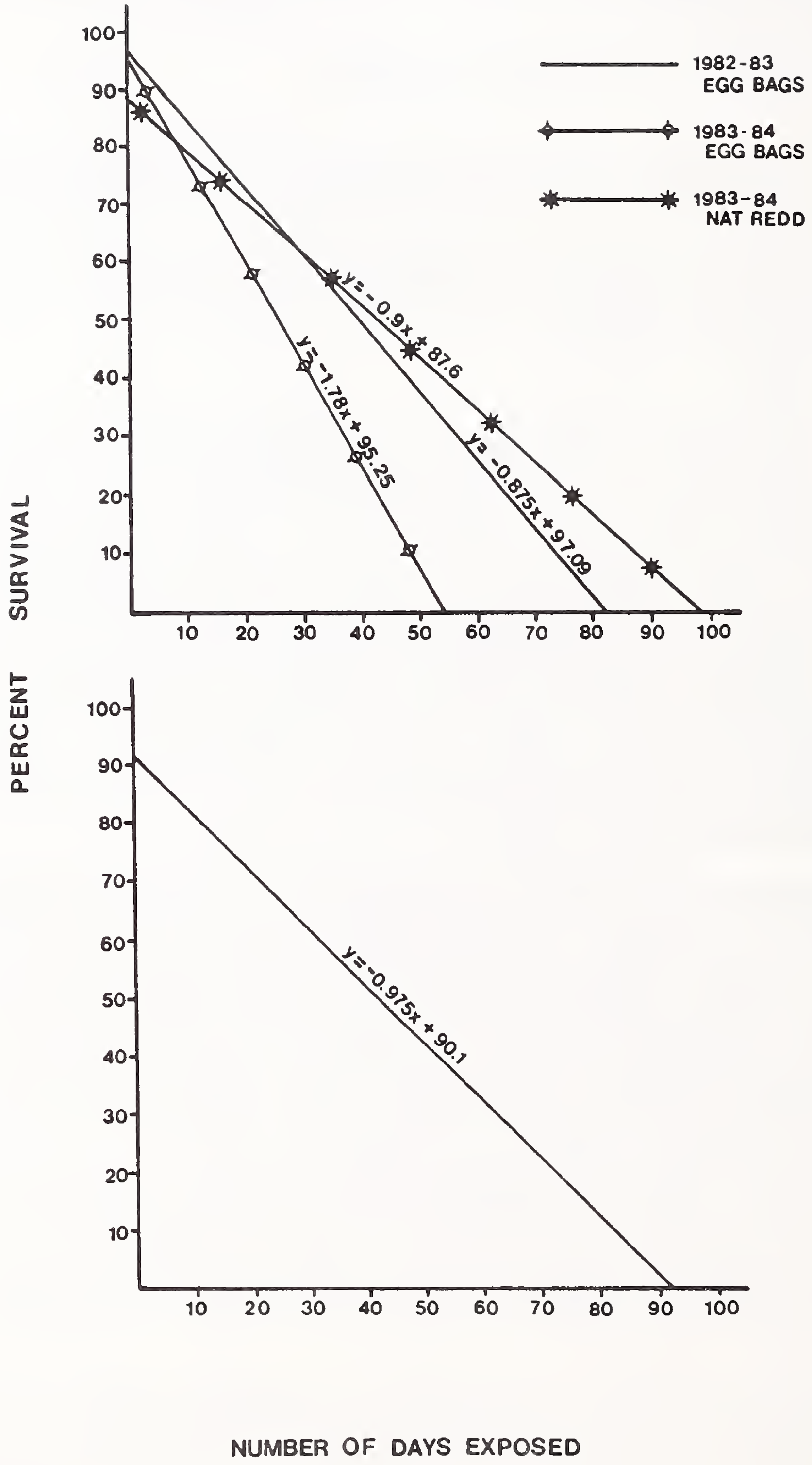

Figure 12. The relationship between percent survival and the number of days exposed by lake drawdown for egg bags at Skidoo Bay in 1982, egg bags at Skidoo Bay and hatchery channels and natural redds in spawning areas above minimum pool in 1983 (upper figure) and for egg bags at Skidoo Bay, Hatchery channel experiment and redds above minimum pool combined.

effect of various groundwater systems had an important yet unquantified impact on prolonging survival in exposed redds. The relationship when the experimental plants and natural redd sampling were combined was $r=-.7246$ ($p\leq.0001$, $n=62$) (Figure 12).

Kerr Dam Operation and Survival

The operation of Kerr Dam and its impact on water level fluctuations and kokanee embryo survival was investigated for the 1983-84 water year and compared to 1982-83. As stated earlier, levels at the time of spawning for the two years were similar near 2889 ft. Following spawning however, lake level decline in 1983-84 was more rapid and at a lower level for a longer period of time. The number of days the lake was held below 2889 ft in 1983-84 increased by 31 percent from 1982-83 (Figure 13).

Based on the survival relationship observed in exposed naturally spawned redds, complete mortality would have occurred in 1983-84 to all redds constructed above 2884.7 ft. This would result in complete mortality to 90 percent of the redds constructed above minimum pool in 1983. Comparing this to 1982-83, complete mortality would have occurred to all redds built above 2886.0 ft or 60% of the redds above minimum pool (Decker-Hess and McMullin 1983).

Because of the late filling of Flathead Lake in 1984 resulting from poor runoff conditions, lake levels did not reach one foot below spawning levels until early June. Even if survival occurred in individual redds as a result of higher groundwater stage velocities, emergence would have to occur by lateral intergravel movement through substrate containing up to 40 percent fines. Lateral movement by emerging fry through gravel wetted only by subsurface flow has been suggested in the literature but not well documented. Studies done by Bams (1969) concluded fry emergence was geotactically induced and an orientation to a secondary mechanism (water movement) would result only from blockage of the primary mechanism by darkness, light or physical barrier. Reiser and White (1981b) reported absence of surface water triggered lateral movement of chinook and steelhead fry through gravel when fine sediments did not limit movement.

Spawning Areas Below Minimum Pool

Redds in Gravel, Yellow and Blue bays were sampled in late January and early February to determine embryonic survival to the eyed stage. Eight percent of the total constructed redds below minimum pool were sampled. Although a higher percentage of redds were sampled in 1983-84, the total sampled egg count was considerably lower for all areas when compared to 1982-83. Eggs were found in only 60 percent of the 25 redds sampled in 1983-84. Of those redds where eggs were found, there was an average of 47 eggs per redd. During the 1982-83 sampling period, an average of 167 eggs per redd were found. It was not known if this low number

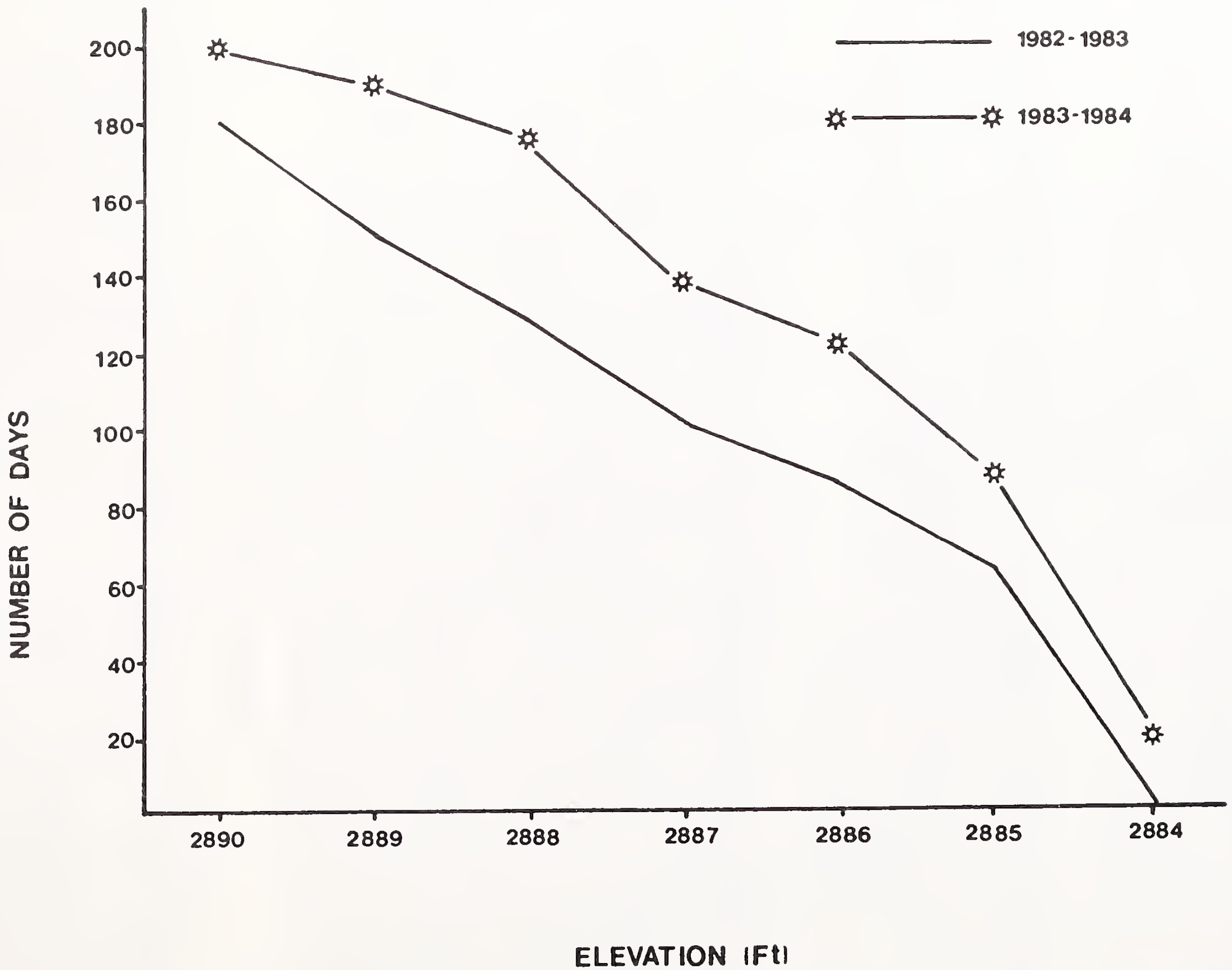

Figure 13. The number of days Flathead Lake was held below elevations 2884 through 2890 ft from 1 November 1982 through May 1983 and November 1983 through May 1984.

of eggs per redd was a result of egg predation or decomposition prior to sampling, egg retention by the female or sampling error. Redds were sampled by the same technique and during the same time period for both years.

Embryo survival in the zone of greatest redd density below minimum pool (2869-2884 ft) was significantly higher from that found below the zone. Survival to the eyed stage in 21 redds in Blue, Gravel and Yellow bays within the zone was 84.8 ($\pm$8) percent ($p\leq.05$) compared to 45 ($\pm$28) percent ($p\leq.05$) in nine redds below this zone. Apparent velocity measurements within the highest redd density zone was higher during the incubation period at Gravel and Yellow bays (Woessner and Brick 1984).

Mean survival to the eyed stage for the three areas was 43 percent. Survival by areas were 96, 4 and 84 percent for Gravel, Yellow and Blue bays, respectively (Appendix B Table 4). Percent survival to the eyed stage at Gravel Bay increased from 83 to 96 percent between 1982-83 and 1983-84. If the low egg count observed in 1983-84 was a result of egg decomposition or predation, a survival estimate would appear higher. No changes in microhabitat conditions could account for this increase in survival.

At Yellow Bay, survival to the eyed stage decreased from 13 percent in 1982-1983 to 4 percent in 1983-1984. Intergravel dissolved oxygen at the time of spawning in 1983 ranged from .35 to 9.6 mg/l (Appendix A Table 4). Sixty-three percent of the stations sampled in the spawning area had concentrations less than 6.5 mg/l with a mean for the entire area of 3.8 mg/l. Dissolved oxygen concentrations increased to acceptable incubation levels by March but was not soon enough to prevent nearly complete mortality in the area. Numerous investigators have documented the effects of low dissolved oxygen concentrations on embryo survival (Alderdice et al. 1958, Silver et al. 1963, Shumway et al. 1964, Mason and Chapman 1965 and Becker et al. 1982).

Survival of 84 percent to the eyed stage was determined at Blue Bay in 1984 for the first time since the study began. This area had been sampled only to fry emergence in the two preceding years, showing a 21 percent survival to this stage.

Experimental Green Egg Plants

To determine the suitability of presently unused habitat in Flathead Lake shoreline areas, green eggs were planted at three sites in November, 1983.

Dr. Richard's Bay

The line planted at 2886.0 ft in Dr. Richard's Bay South was within the boundaries of a spawning area currently used by kokanee. Survival after two months of incubation without exposure

by lake drawdown was 90 percent (Appendix B Table 5). After 31 days of exposure by lake drawdown survival was reduced to 5 percent. After 61 days of exposure, complete mortality had occurred. The groundwater system at Dr. Richard's Bay South dropped instantaneously with lake stage, affording no protection to incubating embryos from dessication or freezing.

The second line in Dr. Richard's Bay South was below minimum pool at 2882.0 ft but kokanee were not currently using the area for spawning. Survival was only 18 percent after one month of incubation. Complete mortality occurred at this line by mid-January.

Substrate composition at both lines was characterized by a low percentage of fines and was nearly identical (Appendix A Table 5). Although intergravel dissolved oxygen concentration at the lower line was 2.5 mg/l in October when the site was selected, similar values at both lines were obtained in December (Appendix A Table 4). Groundwater apparent velocity measurements were taken throughout the incubation period in Dr. Richard's Bay South. Mean apparent velocity was found to decrease with depth and was apparently not strong enough at greater depths to deliver adequate dissolved oxygen or remove metabolic wastes (Woessner and Brick 1984).

Groundwater velocities in Dr. Richard's Bay South were adequate for successful embryo survival only in the upper gravels and only then, prior to lake drawdown.

Gravel Bay

Bennett and Hassemer (1982) documented successful kokanee spawning over a roadfill slope in Cour D' Alene Lake, Idaho to depths of 20 m. The majority of the substrate was greater than 50 mm. Eighty-one and ninety-four percent of the substrate material at the upper (2877.3 ft) and lower lines (2874.0 ft) at the Gravel Bay egg plant was greater than 50.8 mm, respectively.

Survival and development in the two lines varied during the incubation period (Appendix B Table 5). Survival at the upper line remained between 80 to 90 percent throughout the incubation period. Development, however, was delayed considerably when compared to other experimental egg plants. Only one percent of the embryos had hatched by the end of March at the upper line in Gravel Bay compared to 67 percent at Skidoo Bay. A thermograph probe placed at the upper line recorded temperatures 1-2°C cooler than the lake throughout the incubation period.

Survival at the lower line steadily declined throughout the incubation period (Appendix B Table 5). By the end of March, when 35 percent of the embryos had hatched, survival was only 27 percent. Microhabitat data collected at the site did not explain this decreased survival.

Larger substrate habitat outside the spawning area boundary in Gravel Bay showed delayed development and reduced survival in kokanee embryos compared to naturally spawned areas in the bay.

Somers Bay

The eggs planted in an historic, but presently unused, spawning area in Somers Bay showed complete mortality after two months of incubation (Appendix B Table 5). Survival was reduced to 53 and 12 percent at the upper (2888.0 ft) and lower lines (2886.0 ft) respectively, after one month of incubation. It appeared either low intergravel dissolved oxygen concentrations or a high percentage of fines in the substrate composition contributed to the high mortality. Dissolved oxygen was less than 3.0 mg/l at both lines at the time of the plant but had increased above 6.5 mg/l by December. Percent fine material was 45.6 and 21.7 percent at the upper and lower lines, respectively.

Of the three spawning habitat types investigated in 1983-84, survival to emergence only occurred at Gravel Bay. Survival in Gravel Bay was within the levels found in naturally spawned gravels below minimum pool.

FRY EMERGENCE AND DISTRIBUTION

Area Description

Emergence traps were placed in late February over five, six, and eighteen marked redds in Yellow, Blue and Gravel bays, respectively. All but two of the traps in Yellow Bay were buried by gravel from Yellow Bay Creek in late April. No kokanee fry were captured in Yellow Bay. Egg survival to the eyed stage was only four percent in Yellow Bay.

Only eight kokanee fry were captured in Blue Bay. The first was caught on 25 April and the last on 23 May. Survival of eggs to the eyed stage was 84 percent. There was no explanation for this poor survival from the eyed stage to emergence.

Emergence in Gravel Bay began on 10 April, peaked on 17 May and ended on 28 June. A total of 1,661 emerging fry were captured in Gravel Bay. Eleven fry captured in a single trap on 17 May had not totally absorbed their yolk sacs. Tagart (1976) reported 5.3 percent of the fry emerging from the Clearwater River, Washington had not yet absorbed their yolk sacs. Individual trap catch data can be found filed at the Department of Fish, Wildlife and Parks, Kalispell, Montana.

Temporal Distribution

Emergence in deep water areas began at a similar time in 1984 as in previous years, but occurred for a longer period of time (Figure 14). Fry emergence was completed by 8 June in 1982 and 1983 but not until 28 June in 1984. A total of 1,304 temperature units were recorded for the groundwater in Gravel Bay from the peak of spawning on 10 November 1983 to the peak of emergence on 17 May 1984. Slow accumulation of temperature units from late December through mid February may have prolonged development of embryos.

Vertical Distribution

Fry emergence traps were placed in the three spawning areas below minimum pool at elevations varying from 2860.9 ft to 2877.0 ft. Numbers of fry captured in a single trap during one sampling period ranged from one to 151. Fry were captured throughout the zone of vertical redd distribution (Table 3).

Table 3. Vertical distribution of kokanee redds and fry captured in Gravel Bay in 1983-84. This data includes redds which were completely covered by fry traps.

Elevation Zone	#Redds	Number of Redds Trapped	Total Number of Fry Captured	Number of Fry Captured/Trap
2854-2859	8	0	---	0
2859-2864	35	4	956	239
2864-2869	4	4	324	81
2869-2874	39	4	44	11
2874-2879	74	6	337	56
2879-2884*	26	0	---	0
Totals	186	18	1661	

*Two traps placed in this zone were washed out by wave action before emergence began.

Fry Survival to Emergence

Survival to emergence was calculated for Gravel Bay. The fecundity value used was calculated from fish captured in 1982. Based on information collected from a fry emergence experiment

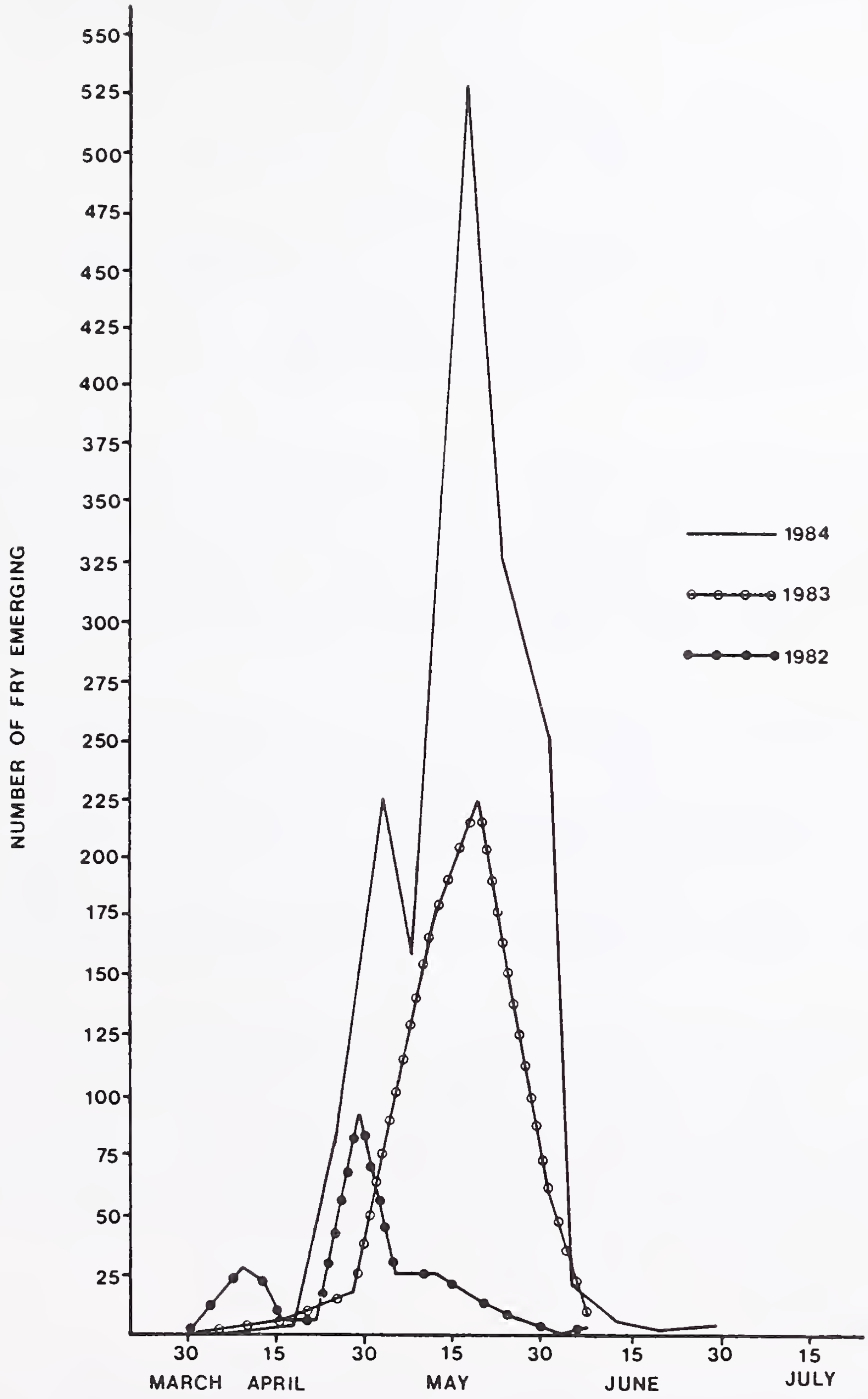

Figure 14. Comparison of temporal distribution during fry emergence from spawning areas below minimum pool for 1982, 1983 and 1984.

completed during this study, the calculation assumed that if a redd was entirely covered by traps, all emerging fry would be captured.

Data used in the calculation were:

- Number of redds: 187
- Mean size of redd: 2.65 m^2
- Area covered by trap: 0.25 m^2
- Number of traps needed to cover an entire redd: 10.6
- Mean number fry captured per trap: 34.8
- Mean fecundity: 1062 eggs/female
- Average Number of females per redd : 1.2

Calculated survival to emergence was 28.9 percent of egg deposition, or 57,484 fry. Average percent survival of the three redds totally covered with traps was 28.3 percent indicating the reliability of the survival estimate. Fry emerged in pockets, as certain individual traps within each cluster captured large numbers of fry while other traps produced few or no fry.

Survival to fry emergence for various salmonid species has been documented in many artifical and natural systems throughout North America (Table 4). Success of natural spawning areas has been highly variable, ranging from a low of 1.05 percent found for sockeye by Foerster (1938) to 77.3 percent for coho (Tagart 1976). In the upper Flathead River system, Fraley (1984) reported survival to fry emergence in five natural spawning areas ranging from 10.4 to 76.0 percent, with an average of 35 percent.

Estimates of fry survival to emergence were made for trapped redds above and below 2869.0 ft, the zone of greatest redd density. Survival above 2869.0 ft was calculated to be 33.6 percent while survival below that elevation was 24.5 percent. The difference between survival estimates above and below 2869.0 ft was not significant, but this may have been due to low sample sizes.

Fry Quality

Fry quality measurements were determined for 411 fry collected from emergence traps in Gravel Bay. Length frequency ranged from 22.0 mm to 27.0 mm with a mean of 24.7 mm (Appendix C Figure 1). The mean condition factor (K) of fry emerging from Gravel Bay was 0.681 ($\pm$.07). Higher condition of emerging fry has been related to an initial advantage in foraging ability and acquisition of feeding territory and less susceptibility to predation, starvation and competition (Wells and McNeil 1970, Stober et al. 1979b, Becker et al. 1982, and Heming 1982). Fry condition at Gravel Bay could not be correlated with fry density or temporal distribution or number of fry captured per foot zone in Gravel Bay (Appendix D

Table 4. Survival to fry emergence for various species of salmonids from natural and artificial systems in North America. Stage of development is also included.

Author	Year	Species	Natural or Artificial redds	Survival percent	Stage of development
Foerster	1938	Sockeye	Natural	1.05-3.23	Fingerling
J. Fish. Board Can.	1956	Sockeye	Natural	1.8-25.0	Fry
Wales & Coots	1955	Chinook	Natural	7-32	Fry
Pritchard	1947	Coho	Natural	11.8-30.4	Fry
Shapovalov & Taft	1954	Coho	Artificial	16.2	Fry
Cederholm & Tagart	Unpub.	Coho	Artificial	2.6-63.8	Fry
Tagart	1976	Coho	Natural (Mean)	.9-77.3 29.8	Fry
Koski	1966	Coho	Natural (Mean)	0-78 27.1	Fry Fry
Ringler	1970	Coho	Natural	17-44	Fry
Hausle	1973	Brook trout	Artificial	62	Fry
Myren	1956	Pink salmon	Natural	.2-20	Fry
Briggs	1953	Silver salmon King salmon Steelhead	Natural Natural Natural	74.3 86 64	Fry Fry Fry
Linsay & Lewis	1975	Kokanee	Natural (Mean)	43	Fry
Fraley	1984	Kokanee	Natural (Mean)	35.2	Fry
Stober et al.	1979a	Kokanee	Natural (altered)	.55-18	Fry

Figures 2 and 3). In Banks Lake, Washington, (Stober et al. 1978) found that condition and density of emerging kokanee fry appeared inversely related in all depth strata except for the shallowest and deepest.

Because only eight fry were captured from Blue Bay, no analysis of fry condition was attempted.

Substrate Composition and Fry Emergence

Fine sediments in the substrate can fill interstitial spaces reducing gravel permeability, apparent velocity and dissolved oxygen. The resulting stress may reduce fry length and prevent or cause premature fry emergence (Peters 1962, Koski 1966 and 1972, and Hall and Lantz 1969, Phillips et al. 1975). Substrate composition of 20 percent fine material created lethal conditions of low dissolved oxygen concentration and high metabolic waste concentrations in redds of steelhead trout and chinook salmon embryos (Bjornn 1969a).

Methods developed by Irving and Bjornn (1984) and Reiser and Bjornn (1979) used substrate composition only to predict survival to emergence. These methods were applied to twelve kokanee spawning areas in Flathead Lake (Table 5). Predicted survival rates were significantly higher than what was actually recorded for 1982 and 1983. Accuracy of these methods to predict survival in shoreline areas was questionable since they do not use other parameters such as dissolved oxygen concentration, groundwater velocity and stage, temperature and duration of exposure. Both methods predicted survival in Gravel and Yellow bays to be at least 87 percent. From fry emergence trap data, survival in Gravel Bay was calculated to be 28.9 percent. In Yellow Bay, no fry were captured.

Because of the high inaccuracy of these methods for kokanee spawning on shoreline areas of Flathead Lake, these predictive methods will no longer be tested.

Table 5. Predicted mean percent survival by substrate composition for twelve shoreline spawning areas using percent fines less than 6.35 mm (Reiser and Bjornn 1979) and cumulative particle size distribution (Irving and Bjornn 1984).

Location	Percent Composition <6.35 mm	Cumulative Particle Size Distribution
Yellow Bay	90	98
Crescent Bay	29	55
Gravel Bay	87	98
Somers Bay	4	0
Blue Bay	80	97
Woods Bay East	62	76
Dr. Richard's Bay North	58	78
Skidoo Bay 1	54	54
Skidoo Bay 2	31	45
Skidoo Bay 3	18	45
Skidoo Bay 4	0	0
Woods Bay West	72	84

Experimental Emergence Study

An experiment to determine intergravel movement by emerging kokanee fry was conducted in channels at the Somers Hatchery beginning on 10 April, 1984. Sac fry were planted in five channels with fine material ranging from 10-40 percent. Flow into all channels was 80 ml/sec. Channel 1 was used as a control and had water flowing over the gravels at all times during the experiment.

The experiment was not completed due to an unexpected interruption of the water source. In channels 1 and 2 (both with 10 percent fines) and channel 3 (20 percent fines) there was an indication that fry were migrating through the gravels into the capture area, but to what degree of success is unknown (Appendix C Table 1). No fry were captured emerging from 30 percent and 40 percent fines. Bjornn (1969b) found that chinook salmon fry emerged readily from gravel with less than 20 percent fines and had difficulty emerging in gravels with 20-40 percent fines. In his experiment, few fry emerged from gravels with 30-40 percent fines.

ANALYSIS OF KERR DAM OPERATION

History of Kerr Dam Operations and Flathead Lake Levels

After considerable analysis of the historic operation of Kerr Dam, it is believed that the dam has, and is continuing to have, a dramatic impact on successful shoreline spawning of kokanee salmon in Flathead Lake.

With the closing of Kerr Dam in 1938, the fluctuation of the upper 10 feet of Flathead Lake between 2883 and 2893 ft changed significantly. Naturally occurring seasonal fluctuations caused a peak near 2893 ft to be reached in May and June. Lake level then receded and was maintained between 2882-83 ft from August through March or April of the following year.

Following the closing of the dam, the lake was filled to 2893 ft by spring runoff and remained at that level until mid-September. A decrease in lake level to a minimum of 2883 ft for energy production and flood control occurred during the fall, winter and early spring months. Although this general pattern of fluctuation has been maintained since five years after the dam closure, variation within certain aspects of the operation have occurred.

Based on evidence that prolonged exposure of salmonid embryos by lake drawdown could cause significant mortality, the number of days the lake was held below various foot increments during the incubation period was investigated (Appendix D Table 1). Initially, length of time the lake was held between 2884 through 2889 ft were analyzed for operational change. These levels were chosen because less than two percent of the redds built above minimum pool were constructed above or below these levels in 1981, 1982 and 1983. The change in the number of days the lake was held below 2885 ft was further investigated because 80-90 percent of the redds constructed in spawning areas above minimum pool in 1981, 1982 and 1983 were built above this level.

The variation in the number of days the lake was at these elevations annually were broken into five time periods (Figure 15). The breaks were based on grouping similar operational patterns at each foot increment by maintaining the smallest variance. The five periods are characterized below.

<u>1940-45</u> - The reservoir operation was in a "transitional" phase between past natural levels and future operation for winter energy production and spring flood control (Appendix D Figure 1). Comparing the number of days below 2885 ft between pre-dam and this early operation, 174 days were below 2885 ft from 1928-39 and 84 days from 1940-45. The lake was approximately six feet higher at the time of kokanee spawning compared to pre-dam levels. Knowing that kokanee were spawning below 2882.8 ft prior to dam

construction, it is unknown how many years it took for conditions above this zone to be attractive to spawning kokanee salmon. Based on the annual collection of adult length measurements it is known that length of kokanee declined from 404 mm in 1938 to 340 mm in 1947 indicating an expanding population and an increase in density. It is therefore likely that a majority of the fish may have still been spawning below minimum pool during this period.

1946-58 - This period marked the complete transition of lake level manipulation to a runoff storage unit for winter energy production and flood control (Appendix D, Figure 2). During this time, extensive egg taking and restocking with fry in shoreline areas was occurring by two hatcheries on the lake. Care was taken during this period to replant fry in the spring from where eggs had been taken in the fall (Art Tangen, pers. comm.).

1959-69 - After the construction of Hungry Horse Dam and the installation of an additional turbine at Kerr Dam, the overall operation became more favorable to the natural reproduction of kokanee salmon in Flathead Lake shoreline areas (Appendix D Figure 3). The lake was held below 2885 ft for an average of only 29 days during this period. Based on embryo survival studies presently being conducted in shoreline spawning areas, the average operation during this period would have caused only 31 percent mortality. Planting of fry in shoreline areas by hatchery personnel in the spring became less systematic and the shoreline population relied much more heavily on natural reproduction during this period.

1970-76 - The number of days the dam was held below 2884 to 2888 ft began to increase and shoreline conditions became less favorable to successful reproduction beginning in 1970 (Appendix D Figure 4). Comparing the 1959-69 period to the 1970-76 period, the number of days the lake was held between 2884 to 2888 ft increased by 43 percent. A significant increase of 83 percent was noticed in the number of days the lake was below 2884 ft. Egg taking and fry planting ceased during this period and shoreline stocks were completely dependent on natural reproduction.

1977-84 - A dramatic increase in the number of days the lake was held below 2884 to 2888 ft and particularly below 2885 ft occurred during this period (Appendix D Figure 5). The number of days the lake was held below 2885 ft increased by 117 percent. Aside from the increases in number of days the lake was held below 2885 ft, the operation during the minimum pool period also changed dramatically. An average minimum pool of 2883.81 ft was reached on 10 March and held for 20 days (Figure 15). Minimum pool was reached up to 25 days earlier than any other period and held up to 20 times as long. The impact of this operation on successful fry

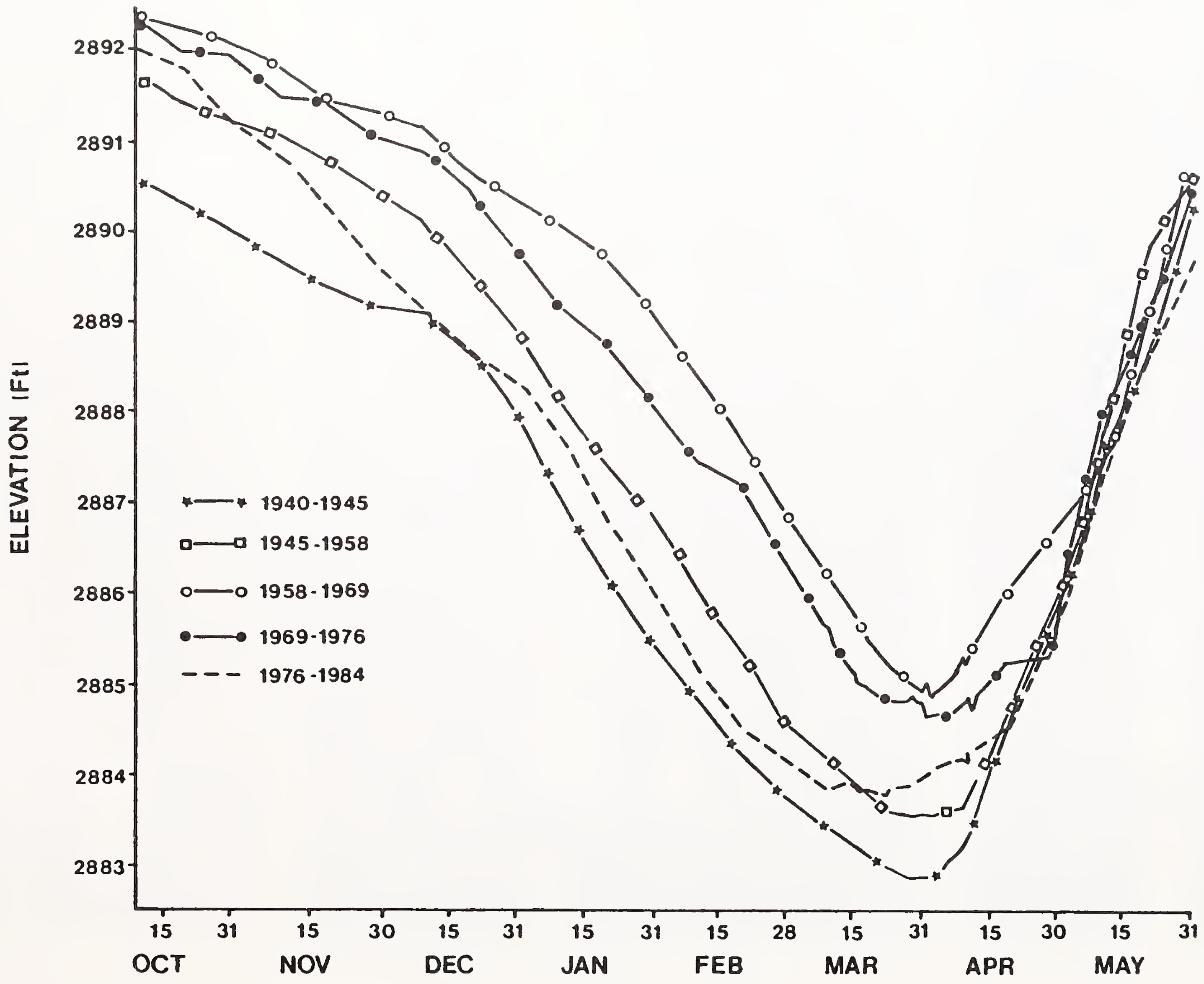

Figure 15. Mean hydrographs for 15 October through 31 May for Flathead Lake for grouped years of 1940-45, 1945-58, 1958-69, 1969-76 and 1976-84.

emergence from shallow shoreline areas could be devastating. Based on current survival studies, this operation would have caused an average of 90 percent mortality to embryos incubating in shoreline gravels above 2885 ft.

Kokanee Shoreline Spawning History

Researchers believe that growth of juvenile sockeye salmon is inversely proportional to population density, i.e. as density increases, growth decreases creating smaller fish (Forester 1944, Bjornn 1957, Johnson 1965 and Rogers 1978). The relationship has been demonstrated although it has not been determined if intraspecific competition is the mechanism. Because kokanee are pelagic schooling fish, close association within the schools would accentuate the interaction more than if the fish were evenly dispersed.

In the early years, after their introduction in 1916 and into the 1960's, shoreline spawning areas in Flathead Lake were used extensively and evidently successfully. Numbers of kokanee in the lake continued to expand based on their decrease in size throughout this period (Figure 16). Stefanich (1953 and 1954) documented "large numbers" (emphasis added) of kokanee in 30 shoreline areas evenly divided on the east and west shores in the 1950's. Egg taking in shoreline areas by hatchery personnel provided millions of eggs to the Station Creek Hatchery into the late 50's and to the Somers Hatchery into the late 60's (unpublished data, MDFWP). Nearly 8,000 adult kokanee were seined from Crescent Bay in five days in the fall of 1951 for egg taking purposes.

During 1962 and 1963, an average of 12 percent of the annual kokanee harvest, or 31,823 kokanee, occurred during the months of October, November and December (Robbins 1966). Kokanee catch rates during these years increased from .8 fish per hour during the May to September period to 2.5 from October to December. Robbins attributed the catch rate increase to the snagging fishery in shoreline areas from mid-October through mid-December. In 1981, Graham and Fredenberg (1982) estimated kokanee harvest during the October to December period at 21,471 or four percent of the annual harvest. Eighty-two percent or 17,600 kokanee of this harvest occurred in October, prior to the observed dates of kokanee congregating in shoreline areas. Only 14 percent of the October to December harvest, or 2,997 kokanee, occurred in November, the month when the majority of spawning occurred. Catch rates in 1981 showed a slight decline from .61 kokanee per hour from May to September to .5 kokanee per hour during the October to December period.

Based on personal interviews with over 50 fishermen that had snagged kokanee from the early 1930's until the present, a general trend in their recollections was observed which identified the years the decline in shoreline spawning kokanee was noticed by the

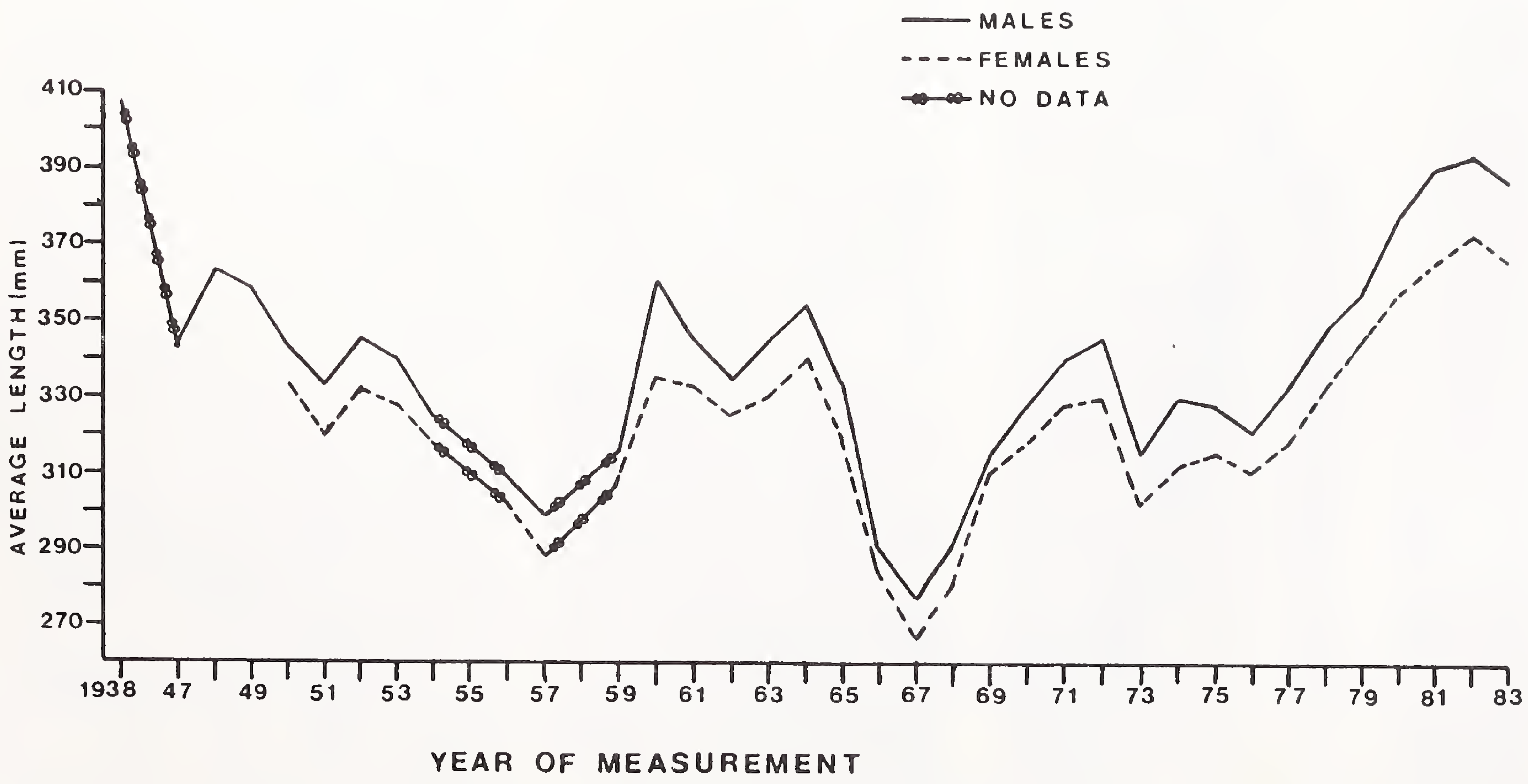

Figure 16. Length of male and female adult kokanee salmon in Flathead Lake for 1938 through 1983.

angling public. Numerous adult spawning kokanee were harvested from shoreline areas throughout the 1950's on the west shore and the 1960's on the east shore. Comments depicted the shoreline snagging fishery during these years as "shoulder to shoulder with 40 people", "everyone catching their limit", "the lake was red with salmon", "easy limit at Yellow, Gravel and Skidoo", "elbow room only", "100's of dead fish washed up on banks". Beginning in the late 1960's and into the early 1970's fishermen generally noticed a decline in numbers of spawning salmon. By the mid to late 1970's fishermen were finding it difficult to get their limit along the shoreline.

Kerr Dam Operation

Because 80-90 percent of the redds constructed above minimum pool in shoreline spawning areas of Flathead Lake during 1981, 1982 and 1983 were above 2885 ft, the numbers of days during the incubation period the reservoir was held below 2885 ft was added into the river gauge height - kokanee length model developed and improved by Fraley and Graham (1982). A weighted three year moving average of number of days below 2885 ft was included in the model. The model was developed for the Flathead River flow conditions to correlate kokanee length with Hungry Horse Dam operation (Graham et al. 1980). A weighted three year moving average of flow conditions during the fall and winter period was the independent variable. This weighting of three years was used in an attempt to explain the kokanee year class interaction. It was felt that the most important interactions in kokanee populations are those between adjacent year classes. At age I+, kokanee would interact primarily with members of their own year class, the previous year class (age II+) and the year class entering Flathead Lake that year (0+). Most adult kokanee mature and spawn in the fall of the fourth year (Age III+). The result of four growing seasons spent in the lake by a particular year class is three years of interaction with the previous year class and three years of interaction with the following year class.

The years correlated were from 1966 through 1983 (Appendix D Table 2). Prior to 1966, a number of factors in addition to the Kerr Dam operation were having an impact on kokanee density in Flathead Lake. Hungry Horse operation in the early years was causing an expansion of river spawners and Somers and Station Creek hatcheries were planting up to 2 million fry into the lake through the late 60's. Unexplained variation in kokanee year class strength as indicated by spawner length may be related to other environmental factors. These factors may affect incubation success (Wickett 1962), growth of kokanee in the lake (Gooland et al. 1974) or differential recruitment from other spawning areas to the lake population.

Female length of kokanee was used in the river-lake model as the dependent variable because they were least likely to have individual variation as a result of kype growth and tissue loss of tail fins as a result of fighting by the males (Figure 16). Female length and three year weighted gauge height difference from the river system alone was highly significant ($r = -.932$ $p<.001$). Female length and three year weighted number of days the lake was held below 2885 ft was also significant but did not account for as much of the varibility as did gauge height ($r = .798$, $p<.001$). When using gauge height difference and the number of days the lake was less than 2885 ft both as independent variables with adult female kokanee lengths, the relationship was highly significant ($R^2 = .926$, $p<.001$). The relationship indicates that kokanee year class strength since 1966 has been highly dependent on the operation of Hungry Horse and Kerr dams.

Although not as strong as the relationship between dam operation and fish length, a relationship between Hungry Horse and Kerr Dams operations does exist ($r^2 = .4404$, $p \leq .05$) (Figure 17). It is felt that this relationship explains part of the relationship observed between kokanee length and Kerr Dam operation but to what extent, is unknown. This situation may explain some of Kerr Dam's effect or may be purely coincidently and insignificant to the biology of the system.

CONCLUSIONS

Based on results from data collected during the 1983-84 field season and an analysis of the present and historic operation of Kerr Dam, it has been concluded that the operation has, and continues to have, an impact on successful kokanee shoreline spawning in Flathead Lake.

Dam operation during the 1983-84 spawning season was characterized by a one meter drop in November during and immediately following spawning, lake level maintenance near or at minimum pool for two months and a late refill as a result of a low snowpack causing a light runoff. Based on a relationship determined between the length of exposure by lake drawdown and kokanee embryo survival, 90 percent of the redds constructed above minimum pool would have suffered complete mortality as a result of the 1983-84 operation.

Various shoreline groundwater systems were found to be capable of prolonging survival in exposed redds during the incubation period. If lake levels do not return to rewet redds by the time of yolk sac resorption, however, mortality to these embryos would still occur. It is presently unknown if any successful emergence can occur by lateral movement through groundwater wetted gravel into the lake.

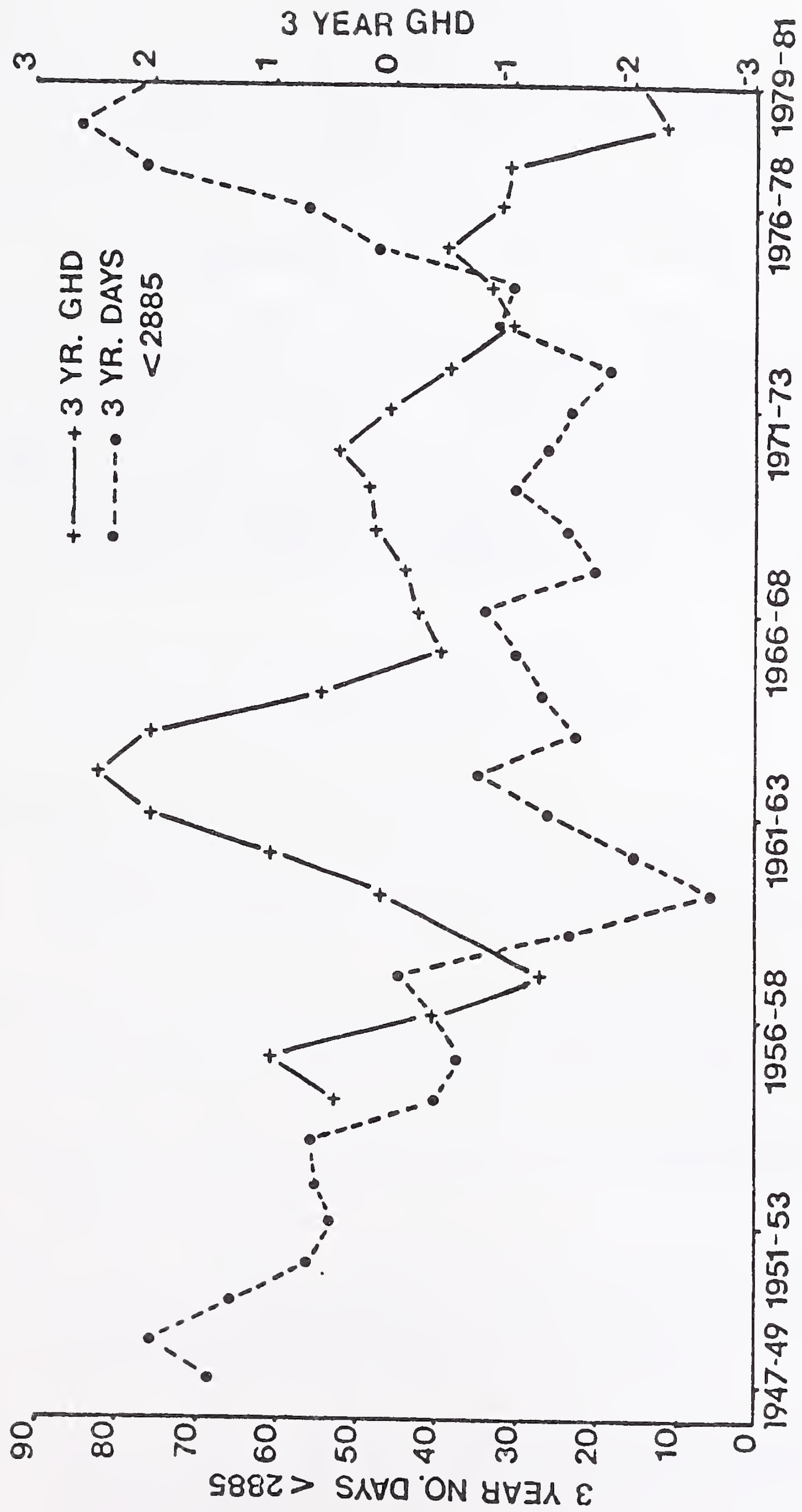

Figure 17. Relationship between Flathead River spawning-incubation gauge height difference and the days Flathead Lake levels were below 2885 ft. during the kokanee incubation period for spawn years 1947-1981.

Analysis of Kerr Dam's operation beginning with the construction in 1938 to the present occurred during 1983-84. The analysis indicated that the number of days the lake has been held below certain operations has varied throughout the dam's history. This variation has been found to be indicitive of five major changes in operation. The present operational pattern beginning in 1977 has been found to be the least conducive to successful kokanee shoreline spawning since the earliest operation of the dam. A significant statistical relationship was found between kokanee length (i.e. fish population density), and the number of days the lake was held below 2885 ft, indicating Kerr Dam's operation has affected the Flathead Lake kokanee population.

Activities during 1984-85 will include quantifying kokanee shoreline spawning habitat. These data will be used to determine actual and potential spawning habitat which will later be used in formulating mitigation recommendations. Probability-of-use curves will be constructed from spawned and unspawned gravels for depth, apparent velocity, dissolved oxygen and substrate composition. Upon completion of the curves, preferred kokanee habitat will be described. Presently unused shoreline habitat suitable for spawning will then be identified.

LITERATURE CITED

Alderdice, D.F., W.P. Wickett and J.R. Brett. 1958. Some effects of temporary exposure to low dissolved oxygen levels on Pacific salmon eggs. Journal Fisheries Research Board of Canada. 15(2):220-249.

Alvord, W. 1975. History of the Montana Fish and Game Department. Montana Department of Fish and Game, Helena.

Bailey, Jack E. and Dale R. Evans. 1971. The low temperature threshold for pink salmon eggs in relation to a proposed hydroelectric facility. Fishery Bulletin: 69(3):587-593.

Bams, R.A. 1969. Adaptations of sockeye salmon associated with incubation in stream gravels. pp. 71-87 In: T.G. Northcote (Editor) Symposium on salmon and trout in streams. University of British Columbia, Vancouver, B.C.

Becker, C.D., D.A. Neitzel, and D.H. Fickeisen. 1982. Effects of dewatering on chinook salmon redds: tolerance of four developmental phases to daily dewaterings. Transactions of American Fisheries Society. 111(5):624-637.

Bennett, D.H. and P.F. Hassemer. 1982. Effects of I-90 construction activities on spawning success of kokanee (Oncorhynchus nerka) in Coeur D'Alene Lake. Department of Fish and Wildlife Resources. College of Forestry, Wildlife and Range Sciences. University of Idaho, Moscow. 77 pp.

Bjornn, T.C. 1957. A survey of the fishery resources of Priest and Upper Priest lakes and their tributaries. Idaho Department of Fish and Game Completion Report F-24-R. 176 pp.

Bjornn, T.C. 1969a. Embryo survival and emergence studies. Idaho Department of Fish and Game Job Completion Report F-49-R-6, Job 6. p. 33-41.

Bjornn, T.C. 1969b. Spawning and emergence of chinook salmon as related to temperature. Salmon and Steelhead Investigations. Job Completion Report. Project No. F-49-R-6, Job No. 8. University of Idaho, Moscow. p. 42-51.

Bowler, B. 1979. Kokanee spawning trends in Pend Oreille Lake. Idaho Department of Fish and Game Job Performance Report, F-73-R-1, Job II. p. 57-77.

Carlander, K.D. 1969. Handbook of Freshwater Fishery Biology. Volume 1. The Iowa State University Press, Ames, Iowa. 752 pp.

Decker-Hess, J. and P.J. Graham.1982. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Montana Department of Fish, Wildlife and Parks, Kalispell.

Decker-Hess, Janet and S.L. McMullin. 1983. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Montana Department of Fish, Wildlife and Parks.

Domrose, R. 1968. Kokanee redd exposure and hatching success in relation to receding Flathead Lake levels. Montana Department of Fish, Wildlife and Parks, Kalispell. 2 pp.

Environmental Protection Agency. 1974. Methods for chemical analysis of water and wastes. EPA-625-16-74-003a. E.P.A. Environmental Monitoring and Support Laboratory. 298 pp.

Foerster, R.E. 1938. An investigation of the relative efficiencies of natural and artificial propagation of sockeye slamon (Oncorhynchus nerka) at Cultus Lake, British Columbia. Fish. Res. Bd. Canada, Jour. 4(3) : 151-161.

Foerster, R.E. 1944. The relation of lake population density to size of young sockeye salmon (Oncorhynchus nerka). Journal of the Fisheries Research Board of Canada 6:267-280.

Foerster, R.E. 1968. The sockeye salmon Oncorhynchus nerka. Journal Fisheries Research Board of Canada, Bulletin 162. 422 pp.

Fraley, J.J. and P.J. Graham. 1982. Impacts of Hungry Horse Dam on the fishery in the Flathead River - Final Report, USDI Bureau of Reclamation, Montana Department Fish, Wildlife and Parks, Kalispell. 91 pp.

Fraley, J.J. and S.L. McMullin. 1983. Effects of the operation of Hungry Horse Dam on the kokanee fishery in Flathead River system. Montana Department Fish, Wildlife and Parks, Kalispell.

Fraley, J.J. 1984. Effects of the operation of Hungry Horse dam on the kokanee fishery in the Flathead River System. Annual Progress Report FY 1984. Fisheries Research and Special Projects Bureau, Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Fredenberg, W. and P.J. Graham. 1982. Flathead River fisherman census, U.S. Environmental Protection Agency. Montana Department Fish, Wildlife and Parks, Kalispell.

Graham, P.J., D. Read, S. Leathe, J. Miller, and K. Pratt. 1980. Flathead River Basin Fishery Study. Montana Department Fish, Wildlife and Parks, Kalispell. 117 pp.

Graham, P., R. Penkal, S. McMullin and P. Schladweiler. 1981. Montana recommendations for a fish and wildlife program. Submitted to Pacific Northwestern Electric Power and Conservation Planning Council. 123 pp.

Graham, P.J. and W. Fredenberg. 1982. Flathead Lake fisherman census, U.S. Environmental Protection Agency. Montana Department Fish, Wildlife and Parks, Kalispell.

Goodlad, J.C., T.W. Gjernes, and E.L. Brannon. 1974. Factors affecting sockeye salmon (Oncorhynchus nerka) growth in four lakes of the Frazer River system. Journal of the Fisheries Research Board of Canada. 31:871-892.

Hall, J.D. and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. pp. 335-375. In: T.G. Northcote, Editor. Symposium on salmon and trout in streams. University of British Columbia, Vancouver, B.C.

Hanzel, D.A. 1964. Evaluation of Kokanee Spawning and Population Density in Flathead Lake and Tributaries. Montana Dept. of Fish and Game. Job Completion Report F-7-R-12, Job II. 10pp.

Hanzel, D.A. 1977. Angler pressure and game fish harvest estimates for 1975 in the Flathead River system above Flathead Lake. Montana Department Fish and Game, Kalispell.

Hanzel, D.A. 1984. Measure annual trends in recruitment and migration of kokanee populations and identify major factors affecting trends. Montana Department of Fish, Wildlife and Parks, Job Performance Report F-33-R-18, Job No.: I-b.

Hassemer, P.F. and B.E. Rieman. 1979. Kokanee life history studies in Priest Lake - spawning evaluation. Idaho Department Fish and Game, Job Performance Report F-73-R-1, Job III. p. 89-105.

Hassemer, P.F. and B.E. Rieman. 1980. Coeur d'Alene Lake spawning evaluations. Idaho Department Fish and Game, Job Performance Report F-73-R-2, Job III. p. 89-95.

Hawke, S.P. 1978. Stranded redds of quinnat salmon in the Mathias River, South Island, New Zealand. New Zealand Journal of Marine and Freshwater Research. 12(2):167-7.

Heming, T.A. 1982. Effects of temperature on utilization of yolk by chinook salmon (Onchorhynchus tshawytscha) eggs and alevins. Canadian Journal of Fisheries and Aquatic Science. 39:184-190.

Hunter, J.W. 1973. A discussion of gamefish in the State of Washington as related to water requirements. Washington State Department Game. 66 pp.

Irving, J.S. and T.C. Bjornn. 1984. Effects of Substrate Core Composition on Survival of Kokanee Salmon and Cutthroat and Rainbow Trout. Technical Report 84-6, Idaho Coperative Fishery Research Unit, Moscow Idaho. 21pp.

Jeppson, P. 1955. Evaluation of spawning areas in Lake Pend Oreille and tributaries upstream from Albeni Falls Dam in Idaho, April, 1954-May 31, 1955, including supplemental information on the life history of kokanee. Idaho Department of Fish and Game, Job Completion Report F-3-R-4 and F-3-R-5, Work Plan 2. 36 pp.

Jeppson, P. 1960. Evaluation of kokanee and trout spawning areas in Pend Oreille Lake and tributary streams. Idaho Department Fish and Game, Job Progress Report F-3-R-10. p. 43-66.

Johnson, W.E. 1965. On mechanisms of self-regulation of population abundance on Onchorhynchus nerka. Mitt. Internat. Verein. Limnol. 13:66-87.

Kimsey, J.B. 1951. Notes on kokanee spawning in Donner Lake, California, 1949. California Fish and Game. 37(3):273-279.

Koski, K.V. 1966. The survival of coho salmon (Onchorhynchus kisutch) from egg deposition to emergence in three Oregon coastal streams. M.S. Thesis Oregon State University, Corvallis. 84 pp.

Koski, K.V. 1972. Effects of sediment on fish resources. Presented at Washington State Department of Natural Resources Management Seminar, Lake Limarick. April 19-20, 1972.

Leathe, S.A. and P.J. Graham. 1982. Flathead Lake fish food habits study - Final Report. Montana Department Fish, Wildlife and Parks, Kalispell. 137 pp.

Lee D.R. and J.A. Cherry. 1978. A field exercise on groundwater flow using seepage meters and min-piezometers. Journal of Geology Education. 27:6-10.

Lindsay, R.B. and S.L. Lewis. 1975. Population dynamics of kokanee salmon in Odell Lake, December 1, 1974 - June 30, 1975. Oregon Department of Fish and Wildlife, Job Progress Report F-71-R-11, Jobs 10 and 11. 12 p.

Lund, Richard E. 1979. A user's guide to MSUSTAT - an interactive statistical analysis package, 1979. Montana State University, Bozeman. 74 pp.

Mason, J.C. and D.W. Chapman. 1965. Significance of early emergence environmental rearing capacity, and behavioral ecology of juvenile coho salmon in stream channels. Journal of Fisheries Research Board Canada. 22:173-190.

McMullin, S.L. and P.J. Graham. 1981. The impact of Hungry Horse Dam on the kokanee fishery of the Flathead River. Montana Department Fish, Wildlife and Parks, Kalispell. 98 pp.

McNeil, W.J. 1964. A method of measuring mortality of pink salmon eggs and larvae. U.S. Fish and Wildlife Service, Fishery Bulletin 66(3):575-588.

McNeil, W.J. 1967. Effect of the spawning bed environment on reproduction of pink and chum salmon. U.S. Fish and Wildlife Service, Fishery Bulletin, Volume 65(2):495-523.

McNeil, W.J. 1968. Survival of pink and chum salmon eggs and alevins. pp. 101-117 IN: T.G. Northcote, Editor. Symposium on salmon and trout in streams. University of British Columbia, Vancouver, Canada.

Montana Department of Fish and Game. 1976. Estimated man-days of fishing pressure by region for the summer and winter season, May 1975-April 1976. Montana Department of Fish and Game, Helena.

Montana Power Company. 1976. Application of the Montana Power Company for a new license for the Kerr Project. To: The Federal Energy Regulatory Commission.

Peters, J.C. 1962. The effects of stream sedimentation on trout emryo survival. Third seminar on biological problems in water pollution. p. 275-279.

Pfeifer, Robert L. 1978. Evaluation of the natural reproduction of kokanee (Oncorhynchus nerka) in Lake Stevens, Washington, as related to the lake limnology and basing. University of Washington, Seattle. M.S. Thesis.

Phillips, R.W., R.L. Lantz, E.W. Claire and J.R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Transactions of the American Fisheries Society. 104(3):461-466.

Potter, D.S. 1978. The zooplankton of Flathead Lake: an historical review with suggestions for continuing lake resource management. Ph.D. dissertation, University of Montana, Missoula.

Reiser, D.W. and T.C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in the western United States and Canada. USDA Forest Service General technical Report PNW-96. 54. pp.

Reiser, D.W. 1980. In situ dewatering of salmonid eggs: Effects on hatching success and fry quality. IN: Proceedings of the Annual Conference of the Western Association of Fish and Wildlife Agencies. 60:443-465.

Reiser, D.W. and R.G. White. 1981a. Incubation of steelhead trout and spring chinook salmon eggs in a moist environment. Progressive Fish Culturist. 43(3):131-134.

Reiser, D.W. and R.G. White. 1981b. Influence of streamflow reductions on salmonid embryo development and fry quality. Idaho Cooperative Fishery Research Unit, Research Technical Completion Report, A-058-IDA. 154 pp.

Reiser, D.W. and R.G. White. 1981c. Effects of flow fluctuation and redd dewatering on salmonid embryo development and fry quality. Idaho Water and Energy Resources Research Institute. University of Idaho. Moscoa, Idaho. Submitted to Bonneville Power Administration, Department of Energy. 88 pp.

Robbins, O. 1966. Flathead Lake (Montana) fishery investigations. 1961-1964. Bureau of Sports Fisheries and Wildlife, Technical Paper. 45 pp.

Rogers, D.E. 1973. Abundance and size of juvenile sockeye salmon, (Oncorhynchus nerka), and associated species in Lake Aleknagik, Alaska, in relation to their environment. Fishery Bulletin 7(4):1061-75.

Royce, W.F. 1959. On the possibilities of improving salmon spawning areas. Transactions of the American Wildlife Conference. 24:356-366.

Seeley, C.M. and G.W. McCammon. 1966. Kokanee. pp. 274-294 IN: A. Calhoun, Editor. Inland Fisheries Management. California Department of Fish and Game.

Shirazi, M.A. and W.K. Seim. 1979. A stream systems evaluation - an emphasis on spawning habits of salmonids. USEPA/EPA - 600/3-79-109. Corvallis Environmental Research Laboratory, Washington.

Shumway, D.L., C.E. Warren, and P. Doudoroff. 1964. Influence of oxygen concentration and water movement on the growth of steelhead trout and coho salmon embryos. Transactions of the American Fisheries Society. 93(4):342-356.

Silver, S.J., C.E. Warren, and P. Doudoroff. 1963. Dissolved oxygen requirements of developing steelhead trout and chinook salmon embryos at different water velocities. Transactions of the American Fisheries Society. 92(4):327-343.

Stanford, J.A., T.J. Stuart, J.D. Coulter, and F.R. Hauer. 1981. Limnology of the Flathead River-Lake ecosystem, Montana. Annual Report, Flathead Research Group, University of Montana Biological Station, Bigfork, Montana. 331 pp.

Stefanich, F.A. 1953. Natural reproduction of kokanee in Flathead Lake and tributaries. Montana Department of Fish and Game, Job Completion Report F-7-R-2, Job III-A. p. 69-74.

Stefanich, F.A. 1954. Natural reproduction of kokanee in Flathead Lake and tributaries. Montana Department of Fish and Game, Job Completion Report F-7-R-3, Job III-A. 10 p.

Stober, Q.J., R.E. Narita, and A.H. Hamalainen. 1978. Instream flow and the reproductive efficiency of sockeye salmon. Job Completion Report, OWRT Project No. B-065-WASH, University of Washington, Fisheries Research Institution. FRI-UW-7808.

Stober, Q.J. and A.H. Hamalainen. 1979. Cedar River salmon fry emigration. University of Washington, Fisheries Research Institution, Final Report. FRI-UW-7917. 52 pp.

Stober, Q.J., R.W. Tyler, C.E. Petrosky, K.R. Johnson, C.F. Cowman, Jr., J. Wilcock, and R.E. Nakatani. 1979a. Development and evaluation of a net barrier to reduce entrainment loss of kokanee from Banks Lake. Final Report, April 1977-March 1979 to U.S. Bureau of Reclamation, Contract No. 7-07-10-50023, University of Washington, Fisheries Research Institution. FRI-UW-7907. 246 pp.

Stober, Q.J., R.W. Tyler, C.F. Cowman, Jr., J. Wilcock, and S. Quinnell. 1979b. Irrigation drawdown and kokanee salmon egg to fry survival in Banks Lake. Final Report. April 1979 - September 1979, to U.S. Bureau of Reclamation , Contract No. 7-07-10-50023, University of Washington, Fisheries Research Institution. FRI-UW-7913. 73 pp.

Tagart, J.V. 1976. The survival from egg deposition to emergence of coho salmon in the Clearwater River, Jefferson County, Washington. M.S. Thesis, University of Washington, Seattle. 101 pp.

Terhune, L.D.B. 1958. The mark VI groundwater standpipe for measuring seepage through salmon spawning gravel. Journal of Fisheries Research Board of Canada. 15:1027-1063.

Wells, R.A. and W.J. McNeil. 1970. Effects of quality of the spawning bed on growth and development of pink salmon embryos and alevins. Special Scientific Report - Fisheries No. 616. United States Department of Interior. U.S. Fish and Wildlife Service. Bureau of Commercial Fisheries. 6 p.

Whitt, C.R. 1957. Age and growth characteristics of Lake Pend Oreille kokanee, 1956. Idaho Department of Fish and Game Annual Summary Report F-3-R-6 and F-3-R-7, Work Plan 2. 20 pp.

Wickett, W.P. 1962. Environmental Variability and Reproduction Potentials of Pink Salmon in British Columbia. H.R. MacMillan Lectures in Fisheries, Symposium on Pink Salmon 1960, pp. 73-86, 1962.

Woessner, W.W. and C.M. Brick. 1983. Groundwater investigations related to the location and success of kokanee salmon spawning, Flathead Lake, Montana: Preliminary Results, April, 1982-June, 1983. Draft Report. University of Montana, Missoula. 125 pp.

Woessner, W.W. and C.M. Brick. 1984. Hydrogeologic conditions during kokanee spawning, egg incubation and fry emergence at selected sites, Flathead Lake, Montana. Rough Draft. University of Montana, Missoula.

APPENDIX A

KOKANEE SPAWNING SURVEY AND MICROHABITAT

Table 1. Daily pram counts and total SCUBA counts of kokanee spawners and new redds built in shoreline areas of Flathead Lake during October, November and December, 1983. Left hand number represents fish seen, right number represents new redds counted.

Area	10-18		10-26		10-30		11-6		11-10		11-15		11-22		11-30		12-5	
	F	R	F	R	F	R	F	R	F	R	F	R	F	R	F	R	F	R
Woods Bay	0	0	60	12	0	6	0	0	0	18	-	-	-	-	0	12	-	-
Yellow Bay	1	0	3	3	0	0	0	0	0	69	-	-	-	-	0	5	0	4
Blue Bay	0	0	0	0	0	1	-	-	25	14	0	26	-	-	0	0	0	5
Talking Water Ck.	0	0	0	0	0	4	0	0	25	11	0	0	-	-	0	0	0	0
Small Dock	0	0	0	0	0	0	0	0	0	8	15	0	-	-	0	14	0	0
Gravel Bay	0	0	15	1	90	18	-	-	0	92	0	0	60	0	0	77	-	-
Dr. Richard's Bay	1	2	6	0	30	4	40	14	95	21	37	2	-	-	-	-	-	-
Skidoo Bay																		
a) East	-	-	-	-	30	5	80	20	96	23	-	0	-	-	-	-	-	-
b) Orange	-	-	-	-	5	2	30	20	75	33	-	11	-	-	-	-	-	-
c) East of Pt.	-	-	-	-	-	-	50	30	-	0	-	11	-	-	-	-	-	-
d) West of Pt.	-	-	-	-	-	-	10	20	-	5	-	25	-	-	-	-	-	-
Somers Bay	0	0	0	0	-	-	60	24	30	1	40	3	0	0	-	-	-	-
Crescent Bay	0	0	45	16	-	-	0	1	0	3	0	0	-	-	-	-	-	-
Totals	2	2	129	32	155	40	270	129	346	298	92	78	60	0	0	108	0	9

Table 2. Comparison of redd counts from the glass bottom pram with chronologically close SCUBA counts for shoreline spawning areas of Flathead Lake, 1981 - 1983.

Location	1981 Pram	1981 Scuba	1982 Pram	1982 Scuba	1983 Pram	1983 Scuba
Woods Bay						
West Shallow	-	-	30	22	20	30
West Deep	25	57	20	50	-	-
East	-	-	-	-	30	46
Yellow Bay*	150	152	70	144	50	58
					60	67
Blue Bay*	30	45	25	34	55	38
					39	45
Gravel Bay*	23	37	40	100	67	110
					92	187
Dr. Richard's Bay						
North	40	63	30	45	23	19
South	40	106	-	-	11	12
Skidoo Bay						
West	-	-	50	43	48	43
East	40	86	50	68	55	66
Gallagher's West	-	-	-	-	25	50
Pine Glen Resort	-	-	50	67	-	-
Total	348	551	365	573	575	771

* Two counts made at each area

Table 3. Total length and age composition with totals and means of adult kokanee salmon collected by seining and gill nets in nine shoreline areas of Flathead Lake in November 1983.

	Length (mm)						Age Composition																	
	Male			Female			Male								Female						Percent Combined			
							II+		III+		IV+		V+		II+		III+		IV+					
	N	Range	X	N	Range	X	N	%	N	%	N	%	N	%	N	%	N	%	N	%	II+	III+	IV+	V+
Bigfork	23	366-419	391	37	345-386	368			24	92%	2	8%					8	89%	1	11%		91%	9%	
Yellow Bay	35	368-434	396	6	366-412	389			23	68%	10	29%	1	3%			1	14%	6	86%		59%	39%	2%
Gravel Bay	35	335-429	389	6	353-389	371			23	77%	7	23%					3	75%	1	25%		76%	24%	
Dr. Richard's Bay	25	343-401	384	9	343-381	368	1	4%	21	91%	1	5%					9	100%			3%	94%	3%	
Woods Bay	24	373-434	394	15	353-376	366			16	73%	6	28%					9	69%	4	31%		71%	29%	
Blue Bay	13	358-409	389	2	363-384	373			7	54%	6	46%					2	100%	-	-		60%	40%	
Skidoo Bay	4	379-389	386	30	353-399	373			9	90%	1	10%					24	83%	5	17%		84%	16%	
Somers Bay	8	340-404	368	12	358-384	378	3	43%	3	43%	1	14%					12	100%	-	-	16%	79%	5%	
Hatchery Bay	26	340-414	368	46	315-391	348	12	55%	10	45%	-	--			25	66%	13	34%	-	-	67%	38%	-	
Lake Overall	195	335-434	384	163	315-412	371	16	9%	138	73%	34	18%			25	20%	81	66%	17	14%	13%	70%	17%	4%

Table 4. Intergravel dissolved oxygen concentrations (in mg/l) by bottom elevation and transect location from Yellow Bay, Skidoo Bay, Dr. Richard's Bay, Woods Bay, Gravel Bay, Pine Glen Resort and Crescent Bay.

Location	Distance From Headstake	Bottom Elevation (ft.)	12/82	3/83	6/83	9/83	12/83	3/84
Yellow Bay								
East Transect	0 (m)	2885.50	1.8	No H2O	8.2	1.1	7.0	8.6
	4	2884.51	1.6	8.7	9.0	4.8	7.0	9.3
	8	2883.86	<1.0	9.4	6.7	7.4	9.1	10.7
	12	2881.56	5.7	7.1	4.7	8.1	9.6	10.8
	16	2876.31	3.6	5.2	0.6	2.9	.35	4.4
	19	2873.36	0.3	<1.0	No H2O	.8	.45	No H_2O
Center Transect	0	2886.15	3.5	10.9	2.5	No H2O	1.1	11.8
	4	2885.50	8.8	10.5	5.6	3.6	1.1	11.7
	8	2885.17	1.6	10.8	8.3	9.1	8.1	11.8
	12	2883.20	2.8	10.5	8.5	7.6	8.2	11.7
	16	2879.59	1.2	10.8	9.0	8.8	2.0	
	20	2873.69	3.1	6.5	7.8	7.8	3.1	
	24	2868.77	1.8	6.1	5.3	4.8	No H_2O	
	26	2866.80	no H_2O	0.6	no H_2O	0.1		
West Transect	0	2881.56	.7	4.2	1.5	1.5	.3	0.4
	4	2877.95	1.9	9.3	5.1	.4	.35	7.7
	8	2872.38	7.6	9.6	4.4	.8	1.2	8.9
	12	2868.44	6.6	7.7	3.8	3.7	2.5	8.0
	15	2865.16	No H_2O		1.9	0	No H_2O	
Gravel Bay			1/5	3/8				
West Transect	0	2882.55	9.2	11.6				
	4	2877.62	9.6	12.1				
	8	2875.00	9.3	12.1				
	12	2872.05	No H_2O					
Center Transect	0	2883.86	8.8	11.9				
	4	2881.23						
	8	2876.64	8.5	12.0				
	12	2873.03		11.3				
	16	2870.08	7.5					
	19	2868.44	4.0	3.3				
East Transect	0	2883.53	9.0	10.6				
	4	2879.92						
	8	2875.00	8.6	10.6				
	12	2871.06						
	16	2867.13	8.5	no H_2O				
	20	2864.17						
	24	2862.20	3.4	6.8				

Table 4. (Continued)

Location	Distance From Headstake	Bottom Elevation (ft.)	12/14	
Blue Bay				
101		2873.66	2.45	
102		2875.99	7.1	
103		2869.64	5.45	
104		2874.68	6.5	
gr. pt.		2879.66	7.5	
			12/9	3/27
Somers		2888.20	no H_2O	Dry
		2888.14	no H_2O	Dry
		2887.76	10.1	Dry
		2887.51	no H_2O	Dry
		2887.49	11.0	Dry
		2887.40	12.1	Dry
		2887.04	No H_2O	Dry
		2886.94	No H_2O	Dry
Hockmark's		2889.29	11.5	11.1
		2888.70	10.9	11.3
		2888.14	11.0	9.5
		2888.07	Dry	
		2887.57	10.7	10.6
		2887.19	8.4	
		2887.18	7.8	10.2
Wood's Bay East		2887.91	11.1	Dry
		2887.63	11.6	Dry
		2887.37	10.0	Dry
		2887.00	11.4	Dry
		2886.94	No H_2O	Dry
		2886.37	10.0	Dry
		2886.35	9.4	Dry
			2/12	3/27
Woods Bay West		2886.73	9.7	Dry
		2886.73	8.5	Dry
		2885.48	Dry	Dry
		2884.87	10.4	Dry
		2884.72	8.1	Dry
		2884.48	8.1	Dry
		2884.10	9.8	11.1
Skidoo Bay			2/12	3/27
Area 1		2887.21	9.4	Dry
		2887.44	9.0	Dry
		2886.10	8.6	Dry
		2886.02	9.2	Dry
		2885.26	8.5	20.2
		2884.84	8.3	9.8

Table 4. (Continued)

Location	Distance From Headstake	Bottom Elevation (ft.)	12/8	3/5
Skidoo Bay (Continued)				
Area 2		2889.46	8.6	Dry
		2888.39	8.9	Dry
		2887.67	8.3	Dry
		2886.82	5.4	9.7
		2885.87	7.9	8.7
		2885.49	8.8	9.2
Area 3		2888.99	6.4	Dry
		2888.69	6.2	Dry
		2888.43	3.8	Dry
		2888.23	4.5	6.8
		2887.89	3.7	Dry
		2887.51	4.3	Dry
Area 4		2888.75	9.8	Dry
		2888.75	11.4	Dry
		2888.23	8.5	8.8
		2887.39	8.0	Dry
		2886.98	6.5	8.1
		2886.43	6.1	Dry
Crescent Bay			12/9	3/5
		2889.12	11.0	11.5
		2886.53	9.3	10.0
		2886.65	5.9	11.6
		2885.00	8.5	10.4
		2884.85	7.5	8.0
		2885.02	8.5	7.2

Table 5 . Percent composition of substrate samples, date sampled and bottom elevation (in ft) for shoreline spawning areas of Flathead Lake.

	Date Sampled	Elevation ft	Percent Composition Sieve Sizes (mm) >50.8	16	6.35	2	.063	<.063
Gravel Bay	12/20/83	2879.0	2.9	91.4	5.6	0	0	0
Gravel Bay	03/09/84	2879.0	13.5	80.9	5.3	.3	.1	0
Gravel Bay	12/20/83	2872.7	14.1	48.4	19.2	14.0	4.1	.3
Gravel Bay	03/09/84	2872.7	17.1	44.5	16.3	19.0	3.0	.1
Gravel Bay Egg Bags (Line 1)		2882.3	85.7	14.4	0	0	0	0
Gravel Bay Egg Bags (Line 2)		2877.3	81.4	17.0	1.6	0	0	0
Gravel Bay Egg Bags (Line 3)		2874.0	94.3	5.7	0	0	0	0
Dr. Richard's Bay No.	01/06/84	2885.0	63.6	18.7	4.4	5.3	7.9	0
Dr. Richard's Bay No.	03/28/84	2885.0	71.8	8.5	5.4	5.4	8.7	.1
Dr. Richard's Bay No.	01/06/84	2887.0	29.8	19.9	17.4	17.1	15.6	.2
Dr. Richard's Bay No.	03/28/84	2887.0	20.2	16.3	41.9	13.1	8.3	.2
Dr. Richard's Bay So.	12/08/83	2887.0	73.2	9.8	6.7	5.3	4.9	.1
Dr. Richard's Bay So.	12/08/83	2885.0	73.8	16.3	3.6	2.3	4.0	0
Swan River	01/06/84		48.1	17.4	15.6	16.2	2.7	0
Swan River	04/02/84		88.5	7.1	3.7	.7	0	0
Swan River	01/06/84		56.2	41.8	1.6	.2	.2	0
Swan River	04/02/84		62.0	25.9	9.6	2.2	.3	0
Blue Bay	12/14/83	2879.6	0	38.2	58.0	3.1	.4	.3
Blue Bay	03/09/84	2879.6	0	38.4	55.6	5.6	.3	.2
Blue Bay	12/14/83	2873.6	4.6	44.9	36.0	13.8	.7	.1
Blue Bay	03/09/84	2873.6	0	42.2	38.0	18.9	.8	.1
Yellow Bay G1	12/14/83	2879.5	3.3	37.9	37.6	19.5	1.5	.2
Yellow Bay G1	03/09/84	2879.5	4.5	68.4	22.1	4.4	.5	.1
Yellow Bay G2	12/14/83	2871.5	0	58.4	39.9	1.4	.2	.1
Yellow Bay G2	03/09/84	2871.5	12	46.6	46.5	5.6	.1	0
Yellow Bay G3	12/14/83	2867.5	0	14.4	55.5	29.2	.9	.1
Yellow Bay G3	03/09/84	2867.5	1.7	25.0	53.4	19.4	.4	.1
Skidoo Bay Area I (East)	11/14/83	2885	8.1	69.3	8.4	4.9	9.3	0
Monitoring Samples	12/08/83	2885	41.7	49.6	3.6	.9	4.2	0
	01/12/84	2885	7.6	34.2	24.0	21.0	13.0	.2
	02/01/84	2885	0	77.4	9.8	2.4	10.4	.1
	02/09/84	2885	4.5	65.9	12.6	2.8	14.2	.1
	03/05/84	2885	9.5	63.1	9.5	3.5	14.3	.1
	05/24/84	2885	2.7	61.3	8.5	6.2	21.2	0
	06/13/84	2885	7.4	40.8	18.6	12.0	21.2	0
Woods Bay East	12/13/83	2885	50.4	48.3	.7	0	.5	0
Woods Bay East	03/05/84	2885	43.0	24.2	7.2	7.7	7.8	.1
Woods Bay East	12/13/83	2887	22.3	35.1	11.5	15.7	15.4	0

Table 5. (Continued)

	Date Sampled	Elevation ft	Percent Composition Sieve Sizes (mm) >50.8	16	6.35	2	.063	<.063
Woods Bay East	03/05/84	2887	41.6	27.7	8.5	10.6	11.5	.1
Woods Bay West	12/13/83	2885	61.6	28.7	6.8	2.7	.2	0
Woods Bay West	03/05/84	2885	33.2	32.5	19.9	10.7	3.5	.2
Woods Bay West	12/13/83	2887	44.3	34.9	6.5	9.2	5.1	0
Woods Bay West	03/05/84	2887	48.6	26.9	7.0	8.7	8.5	.3
Crescent Bay	12/19/83	2885	0	50.0	9.2	17.9	22.8	.2
Crescent Bay	03/30/84	2885	.7	60.5	11.0	13.2	12.4	.1
Crescent Bay	12/19/84	2887	0	63.3	11.3	14.2	11.2	.1
Crescent Bay	03/30/84	2887	1.0	46.6	15.6	20.6	15.9	.2
Somers Bay	12/13/83	2885	35.3	33.9	8.9	9.1	12.0	.8
Somers Bay	03/30/84	2885	31.3	15.7	4.4	5.2	41.2	2.2
Somers Bay	12/13/83	2887	41.6	33.2	9.2	6.8	8.6	.6
Somers Bay	03/30/84	2887	24.7	26.0	5.9	6.5	35.5	1.5
Skidoo Bay Area I (East)	12/08/83	2887	0	76.9	9.8	6.1	7.2	0
Skidoo Bay Area I (East)	03/05/84	2887	6.5	31.3	32.8	11.8	17.4	0
Skidoo Bay Area II (West)	12/12/83	2885	43.4	45.0	4.6	2.1	4.8	0
Skidoo Bay Area II (West)	03/27/84	2885	22.6	38.8	12.8	9.0	16.7	0
Skidoo Bay Area II (West)	12/12/83	2887	0	27.4	22.3	23.0	27.2	.1
Skidoo Bay Area II (West)	03/27/84	2887	16.9	33.6	14.4	16.4	18.6	0
Skidoo Bay Area III	12/12/83	2885	4.0	32.5	25.9	19.9	17.0	.6
Skidoo Bay Area III	03/28/84	2885	0	28.7	29.9	20.6	19.6	1.1
Skidoo Bay Area III	12/12/83	2887	0	55.7	19.2	12.7	12.2	.1
Skidoo Bay Area III	03/28/84	2887	2.4	37.9	29.3	20.9	8.9	.6
Skidoo Bay Area IV	12/13/83	2885	0	0	.1	.9	96.7	2.3
Skidoo Bay Area IV	03/27/84	2885	0	0	0	.1	99.2	.6
Skidoo Bay Area IV	12/13/83	2887	37.7	54.3	2.5	1.1	4.3	0
Skidoo Bay Area IV	03/27/84	2887	15.6	45.1	9.9	6.1	23.2	.2
Skidoo Bay Egg Bags (Line 1)	12/07/83	2888	4.2	29.8	18.5	17.7	29.6	.2
Skidoo Bay Egg Bags (Line 2)	12/07/83	2886	21.0	40.7	14.9	7.9	15.6	0
Skidoo Bay Egg Bags (Line 3)	12/07/83	2884	0	34.8	63.2	2.0	0	0
Skidoo Bay Egg Bags (Line 4)	12/07/83	2882	0	34.8	63.2	2.0	0	0
Somers Bay Egg Bags (Line 1)	12/08/83	2888	0	34.5	19.8	22.0	23.2	.4
Somers Bay Egg Bags (Line 2)	12/08/83	2886	15.8	51.9	10.5	8.9	12.3	.5

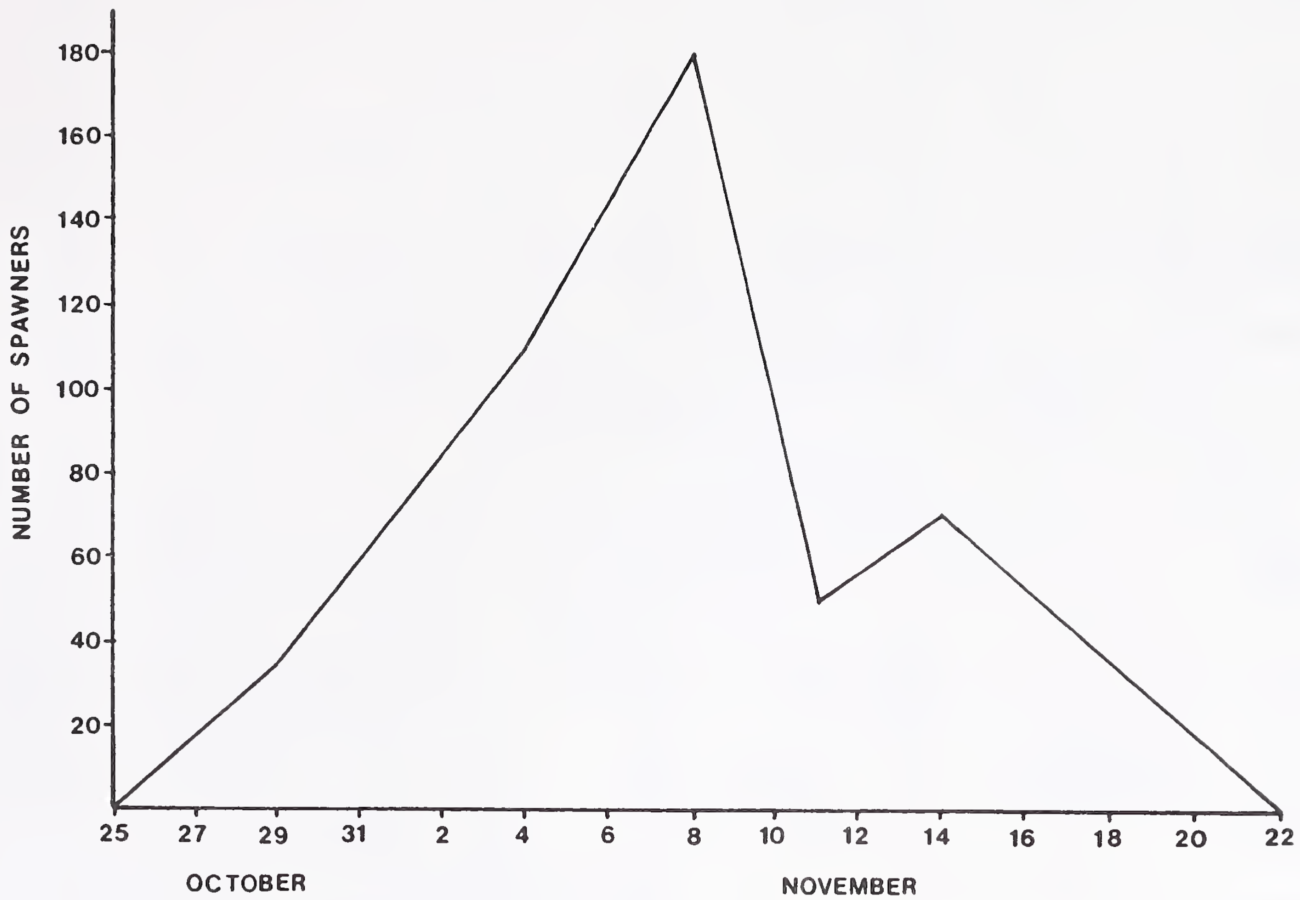

Figure 1. Total spawner days for kokanee salmon in Skidoo Bay Areas I and II from 25 October to 22 November 1983.

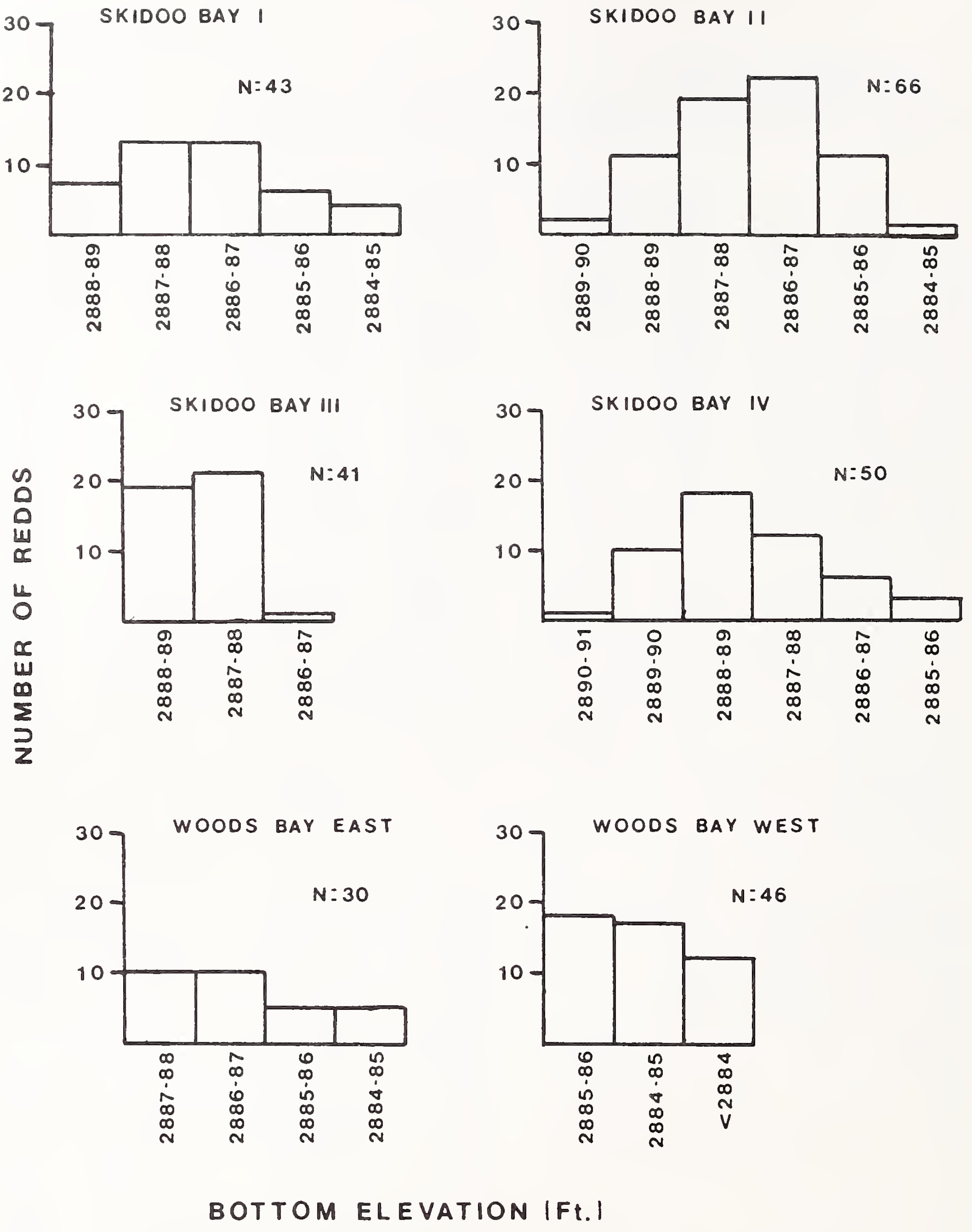

Figure 2. Vertical distribution of redds by bottom elevation at individual spawning areas above minimum pool in Flathead Lake in 1983.

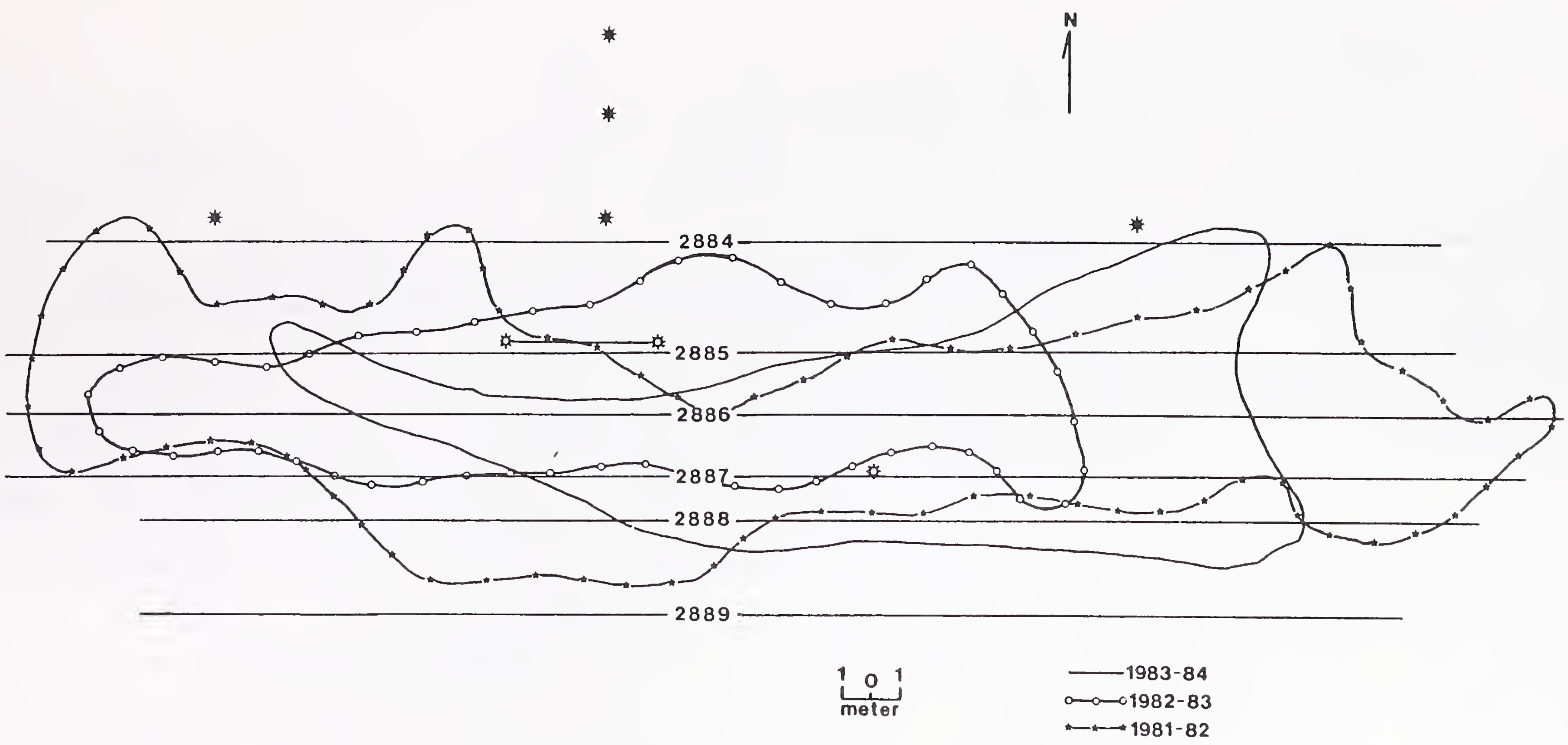

Figure 3. Comparison of spawning area boundaries and location with elevation countour lines (in ft) of Skidoo Bay Area I (formerly Skidoo Bay East) for 1981, 1982, and 1983. Solid stars indicate location of seepage meters. Light stars represent location of substrate composition sample site.

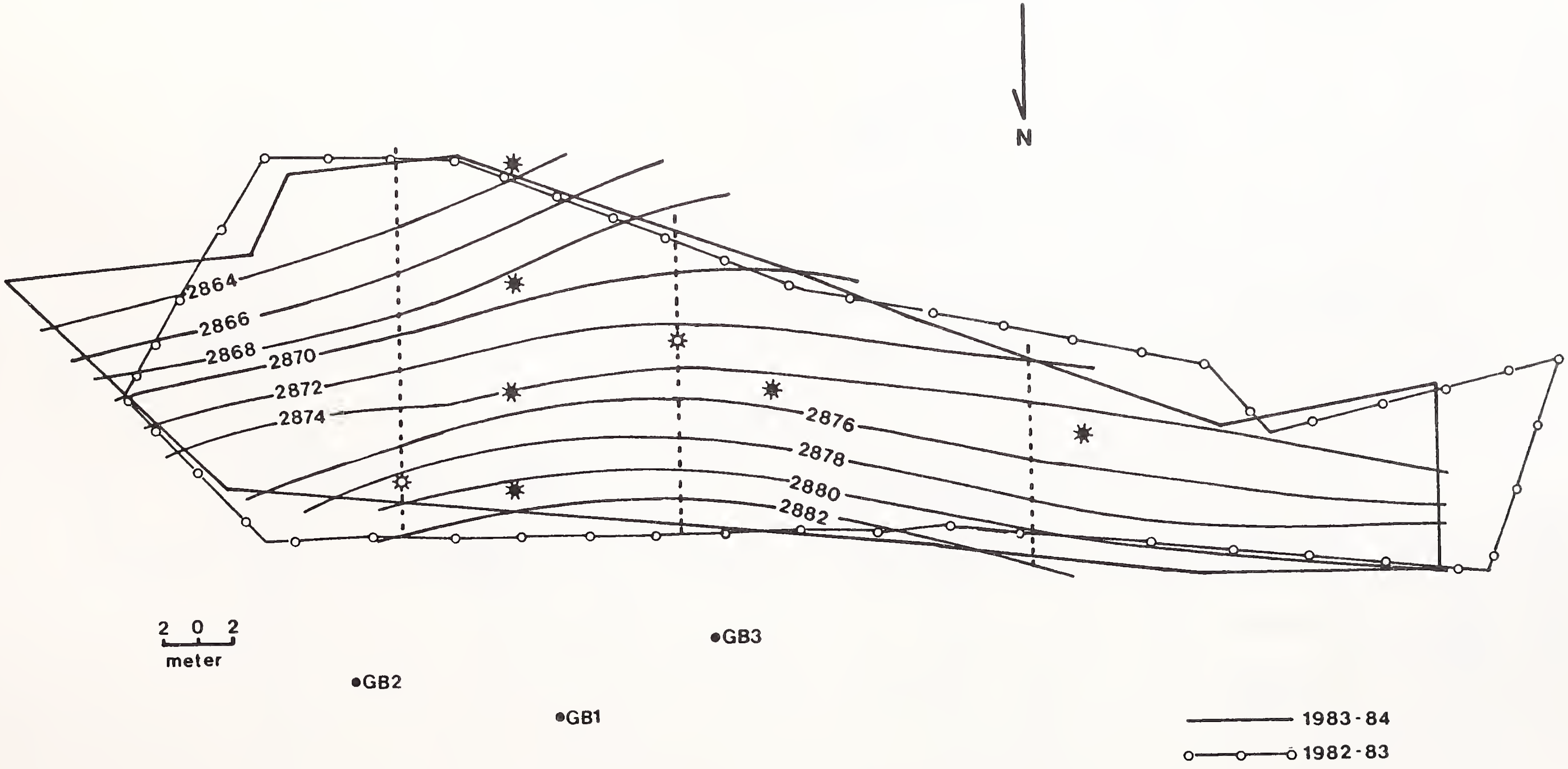

Figure 4 . Comparison of spawning area boundaries and locations with elevation contour lines (in ft) of Gravel Bay spawning area for 1982 and 1983. Solid stars indicate location of seepage meters. Light stars indicate location of substrate composition sample site.

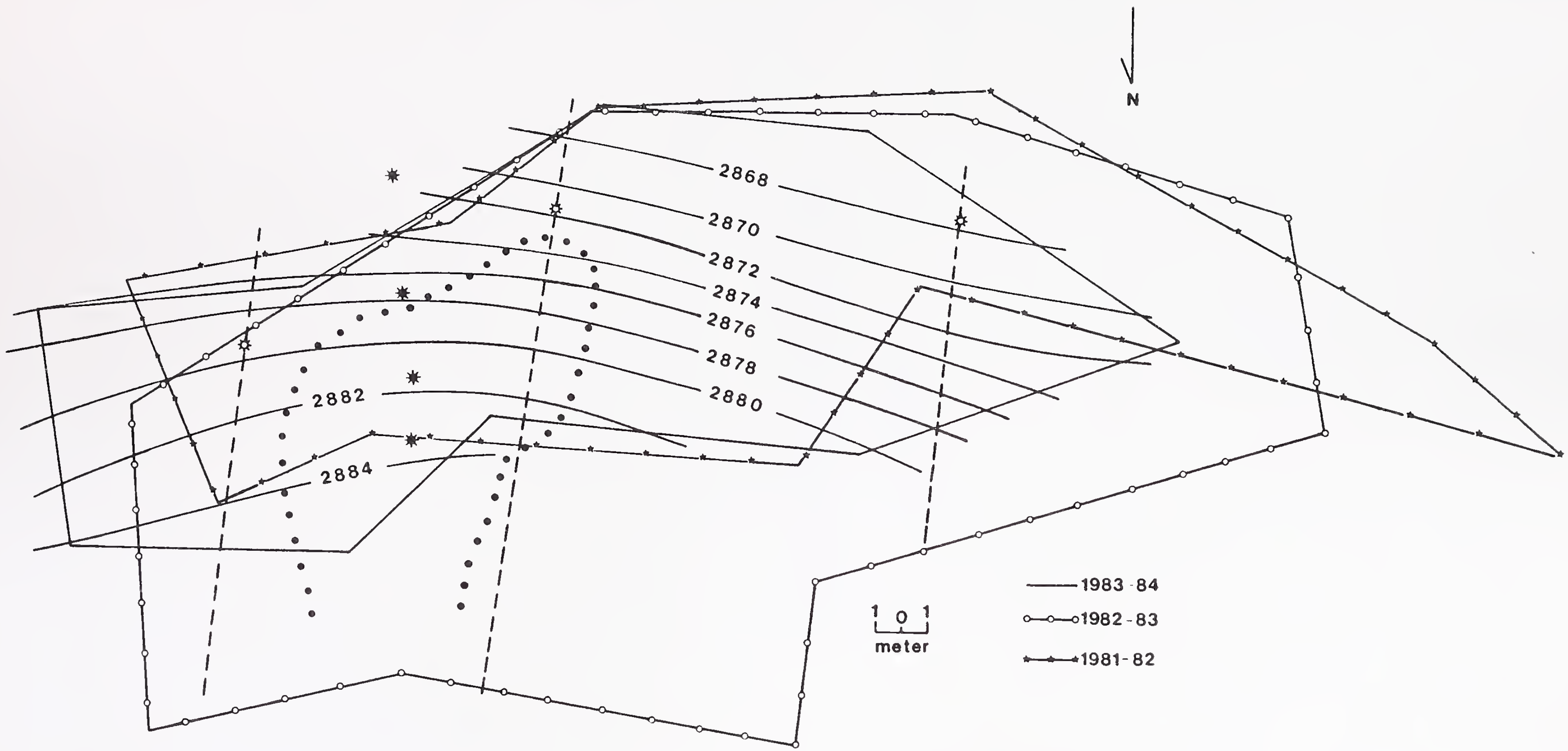

Figure 5 . Comparison of spawning area boundaries and location with elevation contours (in ft) in Yellow Bay for 1981, 1982, and 1983. Solid stars represent locations of seepage meters. Light stars represent locations of substrate sample site. Dotted line denotes area of gravel movement by creek.

APPENDIX B

EMBRYO SURVIVAL AND DEVELOPMENT

Table 1. Mean percent survival to the eyed stage in sampled redds exposed to temperatures below -10^{o}C for less than 6 days at areas above minimum pool. Sampling occurred from 15 January to 15 February, 1984.

	# of Redds Sampled	Mean Elevation of Redds (ft)	Number ofDays Exposed Prior To Sampling	# of Days Exposed To Temperatures Less Than -10^{o}C Prior To Sampling	% Survival	Total Egg Count	Percent Stage Development
Crescent Bay	3	2884.87	0	0	61	310	43% hatch
Skidoo Bay I	4	2885.72	7	2	92.5	464	100% eyed
Skidoo Bay II	4	2885.98	8	4	92	303	100% eyed
Woods Bay West	6	2885.17	3	0	87	452	49% hatch
Woods Bay East	2	2885.36	3	0	94	139	29% hatch
Mean/Total	19	2885.42	4.2	1.2	87	1,668	

Table 2. Mean percent survival to the eyed stage in sampled redds exposed to temperatures less than -10^{o}C for more than 6 days at spawning areas above minimum pool in Flathead Lake. Sampling occurred between 15 January and 15 February, 1984.

	# of Redds Sampled	Mean Elevation of Redds (ft)	Number ofDays Exposed Prior To Sampling	# of Days Exposed To Temperatures Less Than -10^{o}C Prior To Sampling	% Survival	Total Egg Count	Percent Stage Development
Crescent Bay	2	2886.59	22	6	0	12	--
Skidoo Bay I	3	2887.89	50	22	0	243	100% eyed
Skidoo Bay II	3	2887.93	47	22	99	402	100% eyed
Skidoo Bay III	2	2888.99	59	22	29	232	100% eyed
Skidoo Bay IV	3	2889.44	63	22	29	111	100% eyed
Woods Bay East	4	2887.04	45	21	4	518	100% eyed
Somers Bay	2	2888.32	61	22	0	156	--
Mean/Total	19	2887.89	52	20.1	24.2	1,674	100% eyed

Table 3. Mean percent survival at the second sampling for redds above minimum pool of Skidoo and Woods bays. Sampling occurred on 5 and 6 March, 1984.

	# of Redds Sampled	Mean Elevation of Redds (ft)	Number of Days Exposed Prior To Sampling	# of Days Exposed To Temperatures Less Than $-10^{o}C$ Prior To Sampling	Percent Survival	Total Egg Count	Percent Stage Development
Skidoo Bay I	5	2886.18	57	7	65	59	27% hatch
Skidoo Bay II	13	2887.04	67	11	24	383	39% hatch
Skidoo Bay III	2	2888.17	94	22	50	39	88% hatch
Skidoo Bay IV	1	2888.56	97	22	74	0	0
Woods Bay West	6	2885.89	36	4	14.5	256	61% hatch
Woods Bay East	2	2885.36	29	0	0	62	0
MEAN OR TOTAL	18	2886.63	49	7	30.4	981	62.8%

Table 4. Percent survival to the eyed stage for sampled redds at Gravel, Yellow and Blue Bays. Sampling occurred from 15 January to 4 February, 1984.

Location	Number Of Redds	Mean Elevation Ft	Percent Survival	Total Egg Count	State of Development
Gravel Bay	15	2878.11	96	353	100% eyed
Yellow Bay	6	2874.42	3	248	100% eyed
Blue Bay	4	2874.30	84	304	100% eyed
Total or Mean	25	2876.10	43	905	100% eyed

TABLE 5. Elevation, Percent survival and development, stage of development, date exposed and number of days exposed by drawdown and to $-10^{o}C$ for egg bag lines at Dr. Richards, Gravel, Somers, and Skidoo Bays and the Hatchery Channels at Somers.

	REDD ELEVATION	DATE SAMPLED	TOTAL EMBRYOS	PERCENT SURVIVAL EGGS	PERCENT DEVELOPMENT	STAGE*	DATE EXPOSED	NUMBER OF DAYS EXPOSED LAKE DRAWDOWN	NUMBER OF DAYS EXPOSED TO $-10^{o}C$
DR. RICHARDS BAY									
	2886.00	12/16/83	98	91	100	1	01/16/84	0	4
	2886.00	01/16/84	100	86	75	2	01/16/84	0	4
	2886.00	02/16/84	100	5	100	2	01/16/84	31	4
	2886.00	03/22/84	99	0			01/16/84	61	4
	2882.00	12/16/83	99	18	100	2		0	0
	2882.00	01/16/84	100	0				0	0
	2882.00	02/16/84	100	0				0	0
Summary for Dr. Richards Bay (Count = 7):									
Total			696					92	16
Average	2884.28		99	28	53	1		13	2
Maximum	2886.00		100	91	100	2		61	4
Minimum	2882.00		98	0	0	0		0	0
GRAVEL BAY									
	2877.30	12/16/83	100	92	100	1		0	0
	2877.30	01/16/84	91	86	100	2		0	0
	2877.30	02/16/84	100	82	100	2		0	0
	2877.30	03/22/84	98	88	1	3		0	0
	2874.00	12/16/83	99	100	100	1		0	0
	2874.00	01/16/84	93	82	100	2		0	0
	2874.00	02/16/84	99	52	100	2		0	0
	2874.00	03/22/84	100	27	35	3		0	0
Summary for Gravel Bay (Count = 8):									
Total			780					0	0
Average	2875.65		97	76	79	2		0	0
Maximum	2877.30		100	100	100	3		0	0
Minimum	2874.00		91	27	1	1		0	0
SOMERS BAY									
	2888.00	12/16/83	100	53	100	1	12 /05 /83	10	21
	2888.00	01/16/84	100	0			12/05/83	40	21
	2886.00	12/16/83	97	12	100	1	01/16/84	0	4
	2886.00	01/16/84	100	0			01/16/84	0	4
Summary for Somers Bay (Count = 4):									
Total			397					50	50
Average	2887.00		99	16	50	0		12	12
Maximum	2888.00		100	53	100	1		40	21
Minimum	2886.00		97	0	0	0		0	4

REDD ELEVATION	DATE SAMPLED	TOTAL EMBRYOS	PERCENT SURVIVAL EGGS	PERCENT DEVELOPMENT	STAGE*	DATE EXPOSED	NUMBER OF DAYS EXPOSED LAKE DRAWDOWN	NUMBER OF DAYS EXPOSED TO -10ºC
HATCHERY CHANNELS								
2883.	12/16/83	99	98	100	1		0	0
2883.	01/16/84	97	95	100	2		0	0
2885.24	02/10/84	96	93	10	3	02/03/84	7	0
2884.95	03/05/84	50		100	3	03/05/84	0	0
2884.95	03/06/84	25		100	3	03/05/84	1	0
2884.95	03/07/84	40		100	3	03/05/84	2	0
2884.95	03/08/84	50	0			03/05/84	3	0
2883.	12/16/83	100	100	100	1		0	0
2883.	01/16/84	97	97	100	2		0	0
2885.24	03/02/84	45	0	100	3	02/03/84	28	0
2885.84	12/16/83	99	0	100	1	01/27/84	0	0
2885.84	02/10/84	101	87	6	3	01/27/84	14	0
2885.84	03/02/84	96		89	3	01/27/84	35	0
2885.84	03/05/84	100	0	100	3	01/27/84	38	0
2886.39	12/16/83	98	98	100	1	01/13/84	0	0
2886.39	01/16/84	98	98	100	2	01/13/84	3	0
2886.39	02/10/84	98	90	100	2	01/13/84	28	0
2886.39	03/02/84	98	81	90	3	01/13/84	49	0
2883.	12/16/83	99	100	100	1		0	0
2883.	01/16/84	98	100	100	2		0	0
2883.	02/10/84	39	80	20	3		0	0
2883.	03/02/84	45	88	100	3		0	0
Summary for Hatchery Channels (Count = 22):								
Total		1768					208	0
Average	2884.69	80	59	82	2		9	0
Maximum	2886.39	101	100	100	3		49	0
Minimum	2883.00	25	0	0	0		0	0
SKIDOO BAY								
2888.00	12/16/83	100	89	100	1	12/05/83	12	21
2888.00	01/16/84	100	0			12/05/83	44	21
2886.00	12/16/83	99	94	100	1	01/16/84	0	4
2886.00	01/16/84	96	26	100	1	01/16/84	30	4
2886.00	02/16/84	100	0			01/16/84	60	4
2884.20	12/16/83	99	95	100	1	03/21/84	0	0
2884.20	01/16/84	96	88	100	2	03/21/84	0	0
2884.20	02/16/84	94	95	2	3	03/21/84	0	0
2884.20	03/22/84	96	83	100	3	03/21/84	1	0
Summary for Skidoo Bay (Count = 9):								
Total		880					147	54
Average	2885.64	97	63	66	1		16	6
Maximum	2888.00	100	95	100	3		60	21
Minimum	2884.20	94	0	0	0		0	0
Summary for REPORT (Count = 50):								
Total		4521					497	120
Average	2883.54	90	54	72	1		9	2
Maximum	2888.00	101	100	100	3		61	21
Minimum	2874.00	25	0	0	0		0	0

* Stage 1 = Green eggs
2 = Eyed eggs
3 = Hatched

APPENDIX C

FRY EMERGENCE AND DISTRIBUTION

Table 1. Results of kokanee fry emergence studies conducted at the Somers Hatchery. Channel one was the control channel.

	Channel				
	1	2	3	4	5
Percent Fines	10	10	20	30	40
# Fry Planted	200	100	100	100	100
Date:					
	Fry Emerged				
11 April	0	0	0	0	0
13 April	0	0	0	0	0
16 April	0	0	0	0	0
20 April	1	1	0	0	0
21 April	0	0	0	0	0
24 April	1	10	0	0	2
27 April	0	4	4	0	0
30 April	2	9	4	0	0
3 May	10	11	1	0	1
Totals	14	35	9	0	3

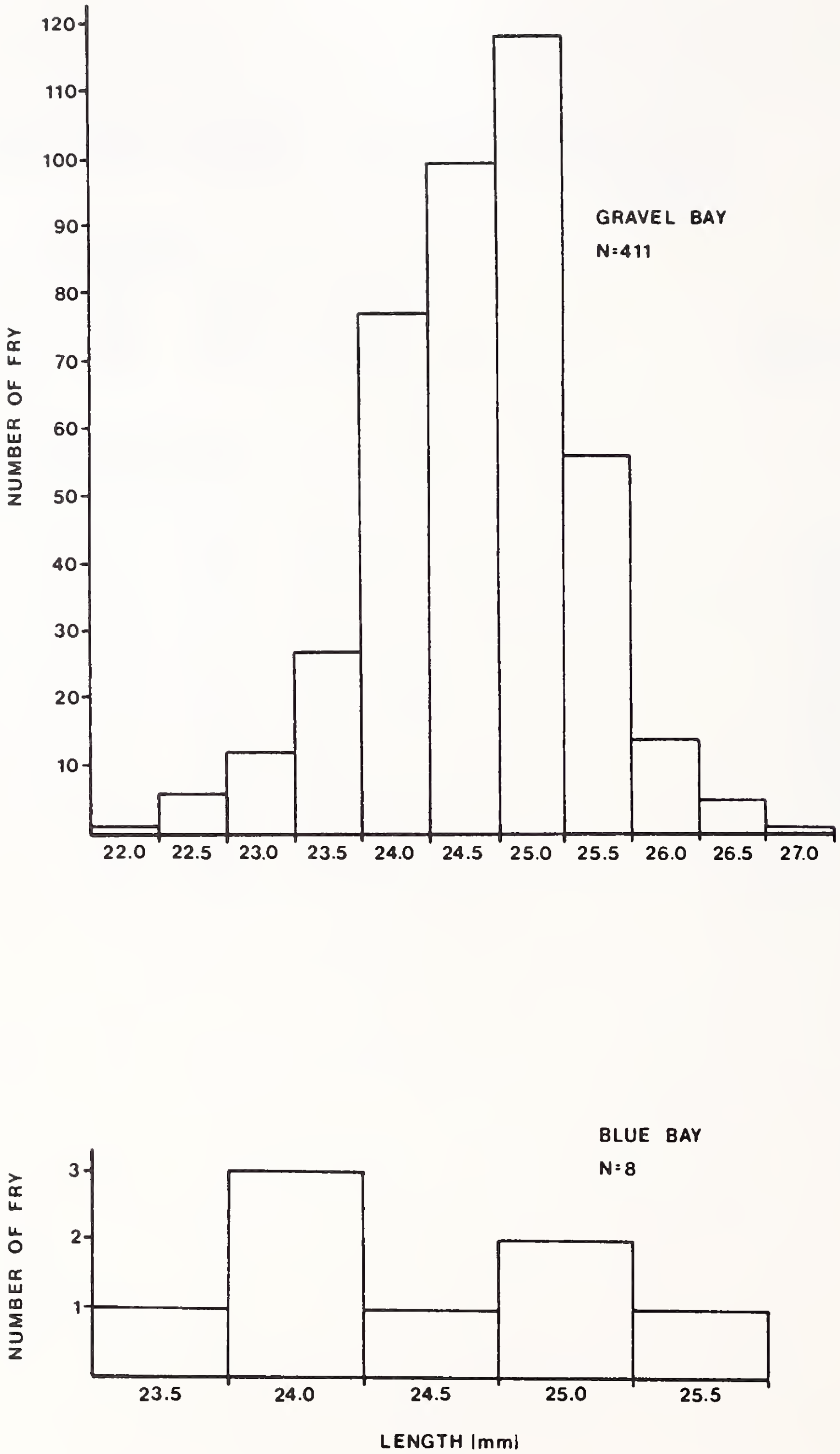

Figure 1. Length frequency distribution of emerging Kokanee fry captured in traps in Gravel and Blue Bays, 1984.

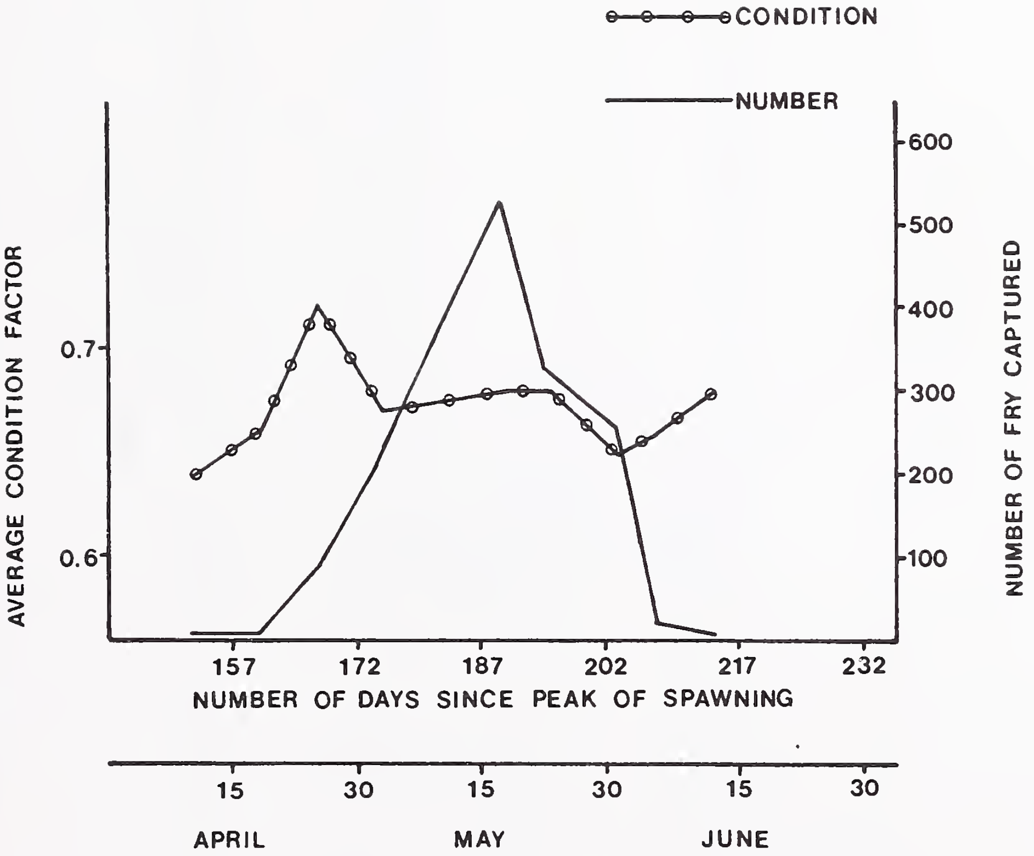

Figure 2. Temporal distribution of emerging fry by condition and number from Gravel Bay from April through June, 1984.

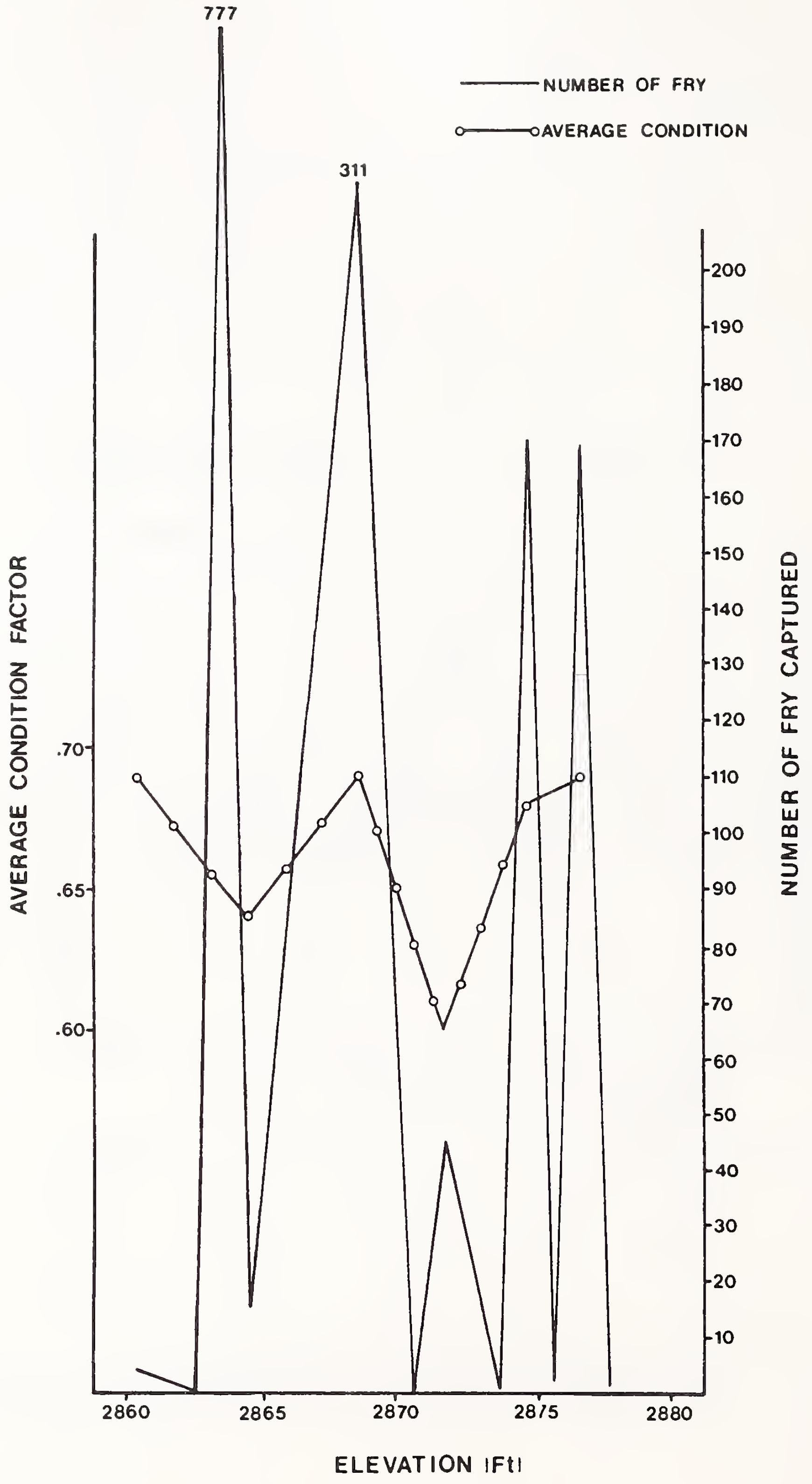

Figure 3. Number and condition factor of emerging fry by depth strata at Gravel Bay from April through June, 1984.

APPENDIX D

KERR DAM

OPERATION ANALYSIS

Table 1. The number of days Flathead Lake was held below 2883 to 2888 ft from 1928 to 1984. Annual minimum pool is also included.

Year	<2883	<2884	<2885	<2886	<2887	<2888	Min.
1928	52	61	61	61	61	61	2882.67
1929	178	181	181	181	181	181	2881.30
1930	192	196	200	206	209	212	2881.37
1931	195	211	212	212	212	212	2881.75
1932	120	195	200	204	213	213	2881.64
1933	119	144	178	212	212	212	2882.23
1934	48	124	173	194	197	202	2881.92
1935	201	208	212	212	212	212	2881.54
1936	201	203	205	207	210	213	2881.29
1937	211	212	212	212	212	212	2881.23
1938	105	108	110	181	212	212	2882.06
1939	32	57	149	198	211	212	2882.40
1940	10	85	112	121	121	166	2882.91
1941	0	54	84	102	120	120	2883.03
1942	43	66	90	100	110	113	2882.40
1943	27	51	66	76	102	132	2882.54
1944	11	56	91	114	121	123	2882.85
1945	6	48	63	80	97	120	2882.95
1946	0	22	47	60	75	88	2883.42
1947	0	22	50	66	82	100	2883.60
1948	26	54	72	86	97	108	2882.84
1949	14	60	81	97	106	113	2882.88
1950	0	55	74	88	97	107	2883.31
1951	0	19	41	61	71	95	2883.67
1952	8	42	57	68	78	124	2882.92
1953	0	39	58	82	135	161	2883.18
1954	0	29	48	120	120	120	2883.27
1955	0	28	65	74	86	115	2883.61
1956	0	0	0	76	113	135	2885.12
1957	0	47	59	78	109	120	2883.08
1958	1	43	56	70	94	109	2883.00
1959	0	0	16	45	63	87	2884.07
1960	0	0	0	16	27	55	2885.17
1961	0	0	0	0	40	90	2886.63
1962	0	34	50	61	75	88	2883.22
1963	0	0	20	40	56	64	2884.40
1964	0	11	39	45	56	63	2883.67
1965	0	0	0	20	33	64	2885.04
1966	0	21	50	62	68	76	2883.44
1967	0	5	32	56	62	68	2883.91
1968	0	0	20	40	50	80	2884.14
1969	0	0	8	26	59	82	2884.57
1970	0	0	45	65	88	107	2884.08
1971	0	0	31	49	71	92	2884.18
1972	0	0	0	24	77	98	2885.38
1973	0	32	46	55	65	82	2883.68
1974	0	0	0	10	37	53	2885.87
1975	0	45	60	80	88	96	2883.41
1976	0	0	20	46	63	78	2884.50
1977	0	37	69	91	99	107	2883.35
1978	0	32	74	89	104	124	2883.34
1979	0	64	87	100	108	124	2883.17
1980	0	71	89	104	116	121	2883.13
1981	0	0	48	64	79	89	2884.35
1982	0	5	67	92	106	129	2883.75
1983	0	0	62	84	104	125	2884.03
1984	0	18	85	121	135	169	2883.80

Table 2. Female kokanee length, river gauge height and lake level days, Flathead System 1951-1983.

Kokanee Spawn Year	Mean Kokanee Length	Water Years Affecting Kokanee Length	3-Year Mean No. Days Below 2885 Feet	3-Year Mean* River Gauge Height Difference
1951	320	1947-49	68	-
1952	332	1948-50	76	-
1953	328	1949-51	66	-
1954	318	1950-52	56	-
1955	-	1951-53	53	-
1956	302	1952-54	55	-
1957	288	1953-55	56	-
1958	-	1954-56	40	0.56
1959	308	1955-57	37	1.03
1960	335	1956-58	40	-0.30
1961	319	1957-59	45	-0.96
1962	325	1958-60	23	-1.22
1963	328	1959-61	05	-0.42
1964	334	1960-62	15	0.13
1965	315	1961-63	26	1.09
1966	287	1962-64	35	2.06
1967	268	1963-65	22	2.44
1968	271	1964-66	27	2.20
1969	306	1965-67	30	0.65
1970	321	1966-68	34	-0.36
1971	331	1967-69	20	-0.29
1972	332	1968-70	23	-0.14
1973	304	1969-71	30	0.22
1974	315	1970-72	26	0.23
1975	316	1971-73	23	0.41
1976	311	1972-74	18	0.06
1977	321	1973-75	32	-0.43
1978	332	1974-76	30	-0.97
1979	344	1975-77	47	-0.87
1980	363	1976-78	56	-0.48
1981	372	1977-79	76	-0.94
1982	379	1978-80	84	-2.31
1983	373	1979-81	76	-2.06

* Difference between mean river gauge elevations during the December through March (incubation) and November (spawning) periods. Positive values indicate conditions favorable for kokanee egg incubation. Negative values indicate poor incubation conditions.

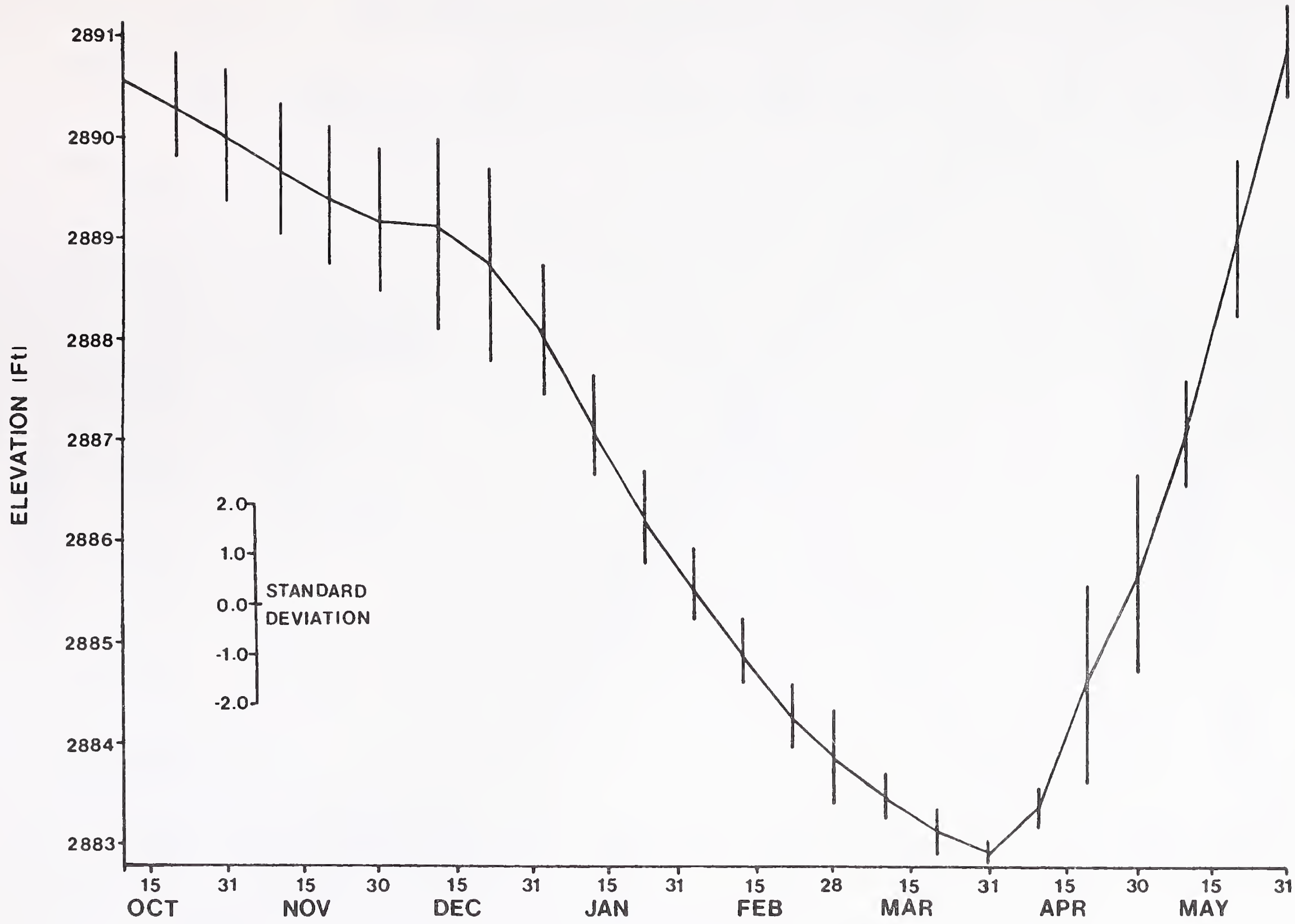

Figure 1. Mean hydrograph for Flathead Lake from 1 October to 31 May for the years 1940-45. Standard deviations are included.

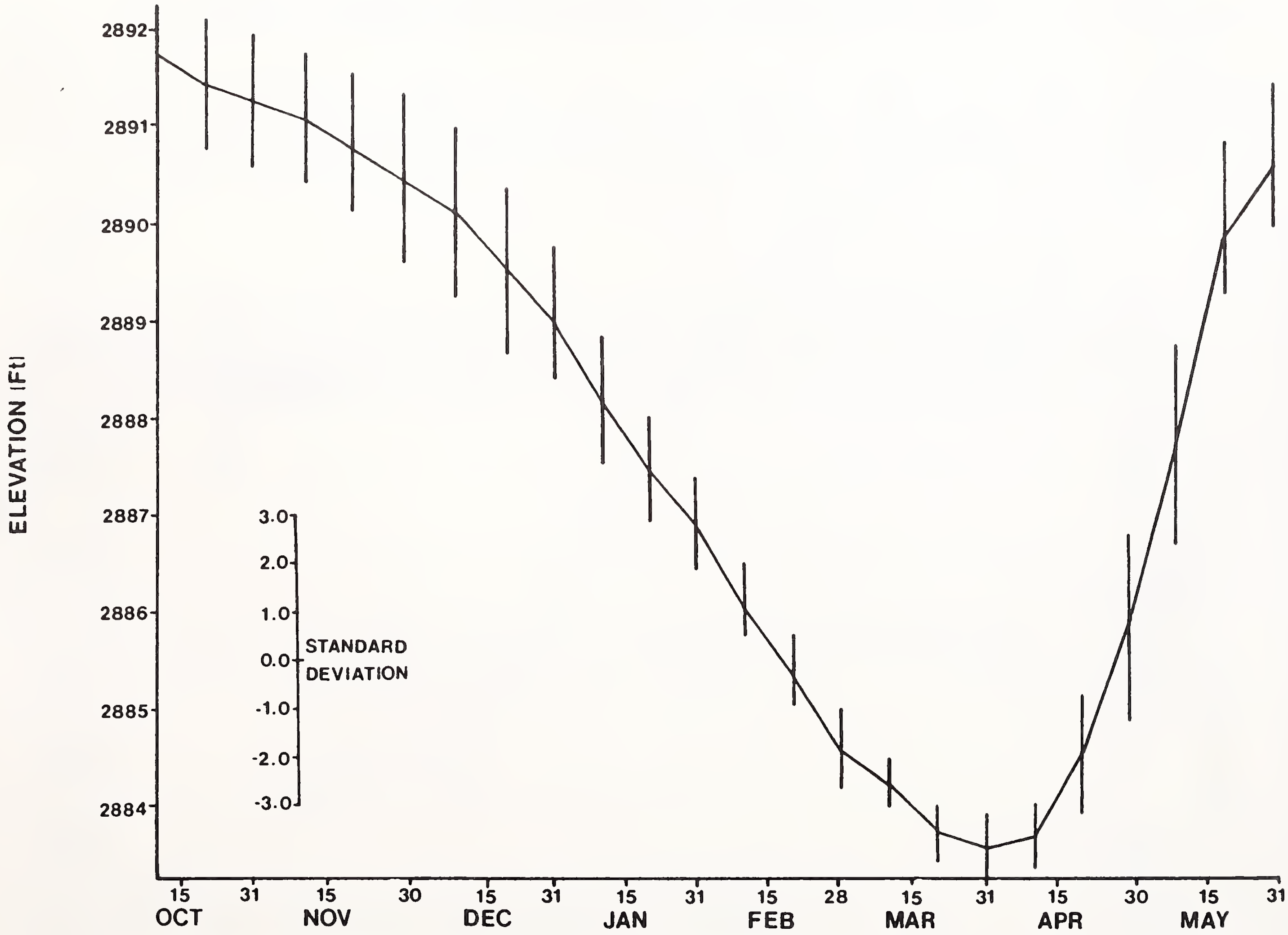

Figure 2. Mean hydrograph for Flathead Lake from 1 October to 31 May for the years 1945-58. Standard deviations are included.

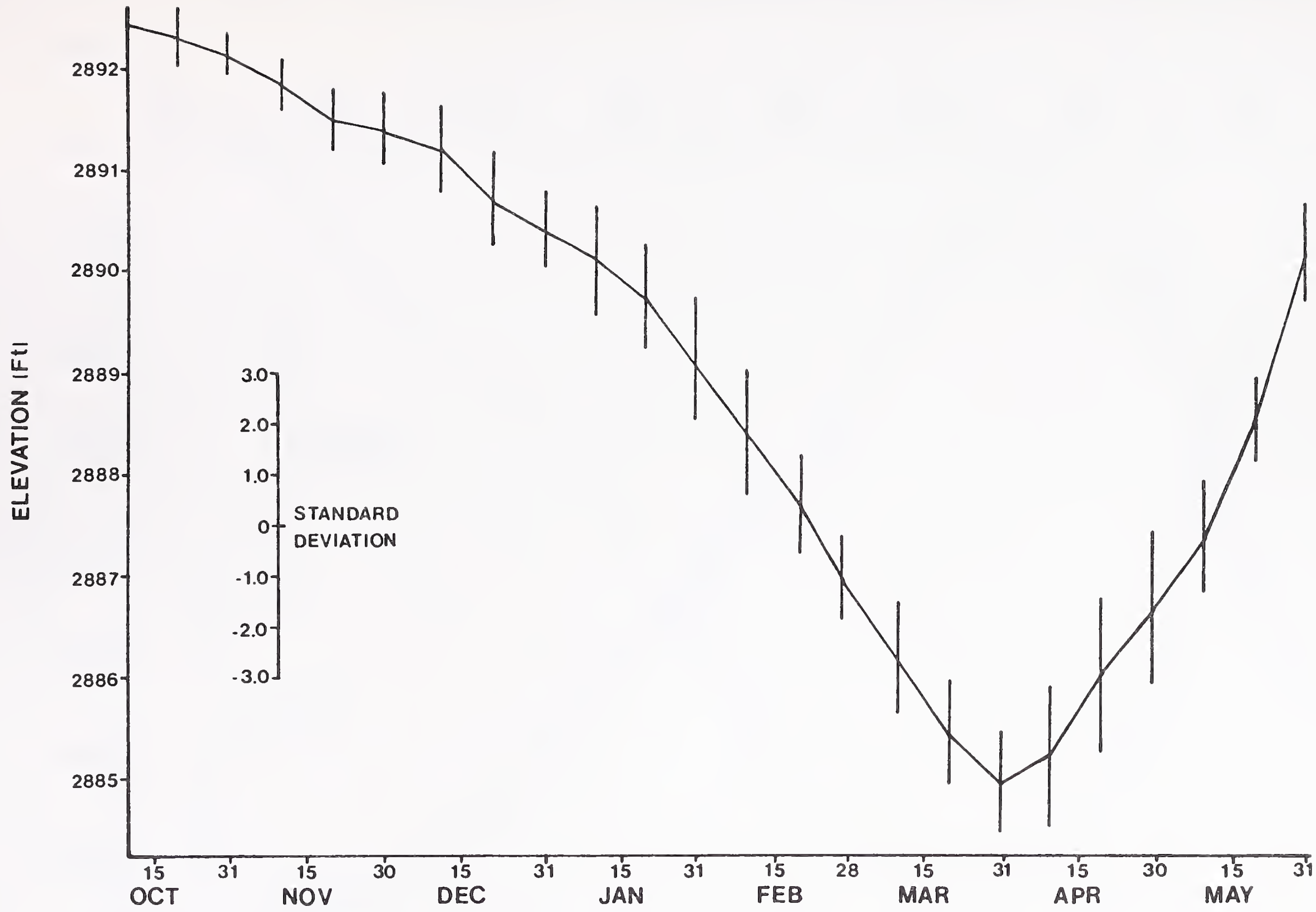

Figure 3. Mean hydrograph for Flathead Lake from 1 October to 31 May for the years 1958-69. Standard deviations are included.

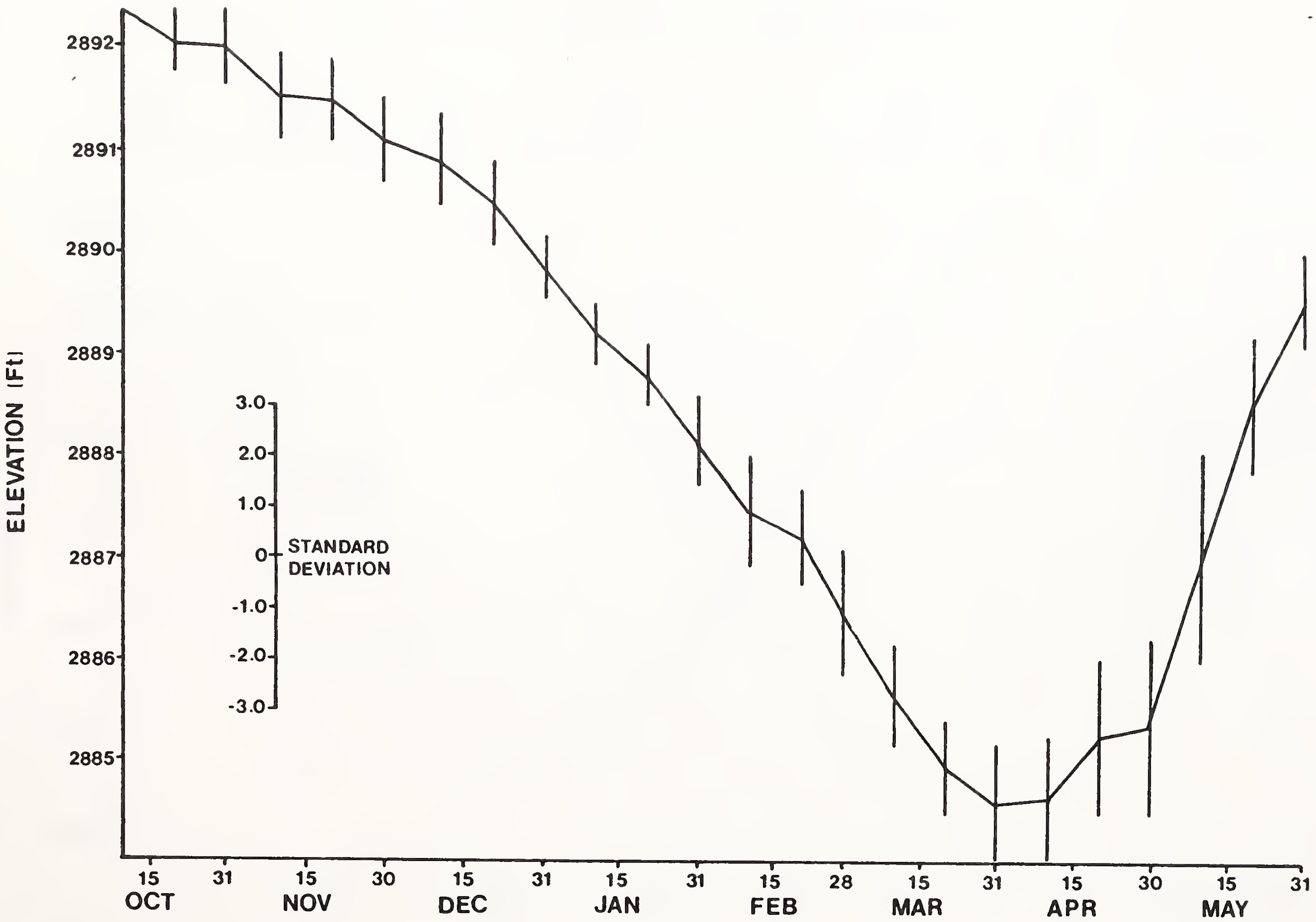

Figure 4. Mean hydrograph for Flathead Lake from 1 October to 31 May for the years 1969-76. Standard deviations are included.

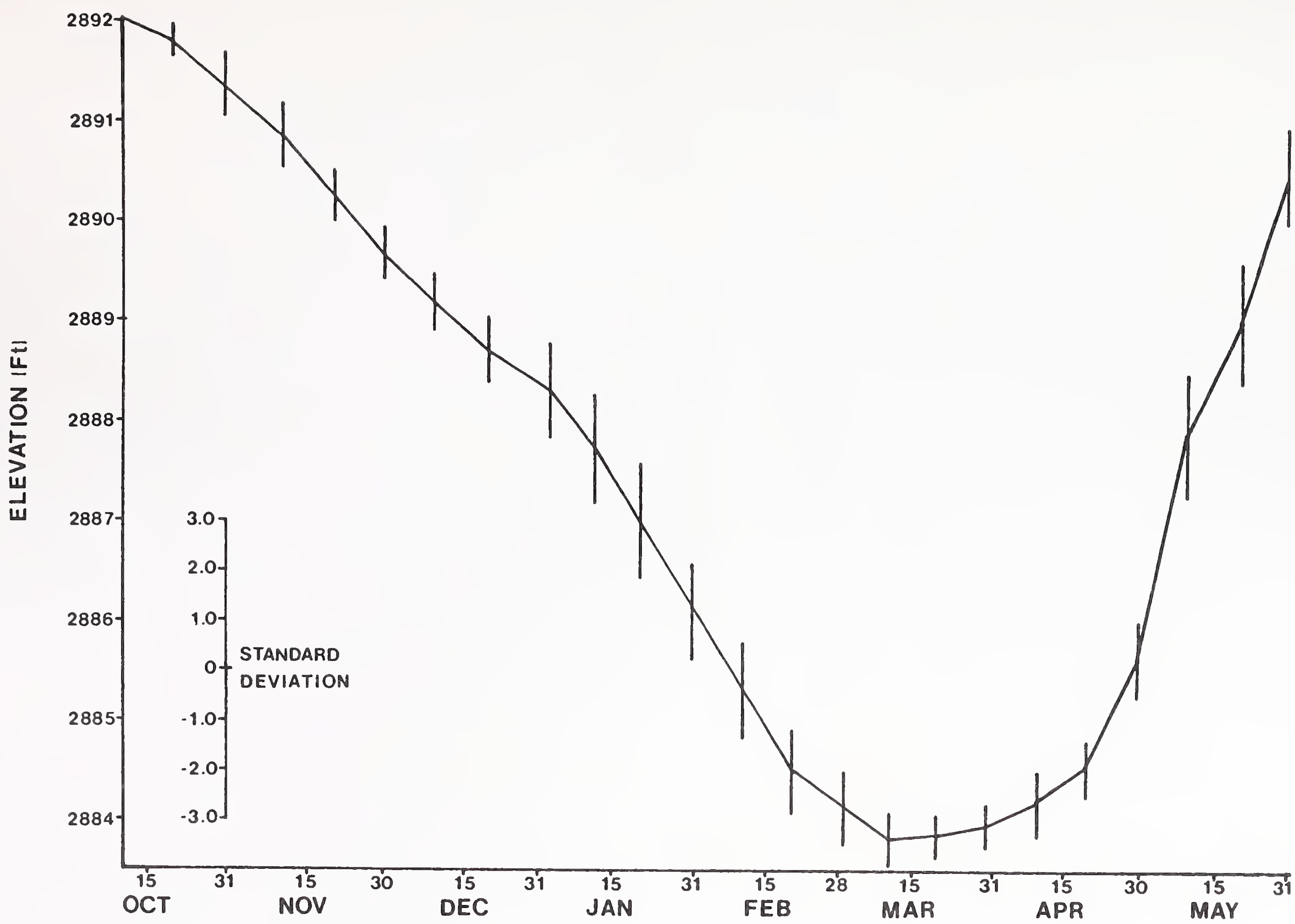

Figure 5. Mean hydrograph for Flathead Lake from 1 October to 31 May for the years 1976-84. Standard deviations are included.

APPENDIX E

KOKANEE FOOD AVAILABILITY

ABSTRACT

Flathead Lake zooplankton populations were monitored in 1984. Water temperatures were quite similar to those seen in 1982, but the maximum average temperature in 1983 was lower than in any of the three previous years. Thermal stratification began in mid-June and lasted through mid-October. The average secchi disc reading was 7.9 m. Three copepod and four cladoceran species were collected. Total zooplankton density did not change significantly since 1981, although individual species exhibited trends indicating declining densities. *Diaptomus ashlandi* was the single most numerous organism collected and its density was positively correlated to total zooplankton density ($r = 0.98$, $p<.001$).

INTRODUCTION

Monitoring of Flathead Lake zooplankton populations was continued in 1983 as described by Decker-Hess and McMullin (1983). This sampling program was designed to monitor zooplankton population trends in Flathead Lake on an annual basis and to note any significant shifts in zooplankton species composition or density. A major change in the zooplankton population could have substantial effects on the kokanee salmon of the entire Flathead drainage.

METHODS

A sampling program designed to monitor zooplankton population trends in Flathead Lake continued in 1983. With one exception, methods remained the same as in previous years (Decker-Hess and McMullin 1983). Counts of *Leptodora* and *Epischura* were made by diluting the sample to 150 ml and extracting a 10 ml subsample for examination.

Leathe and Graham (1982) found that the zooplankton composition and density of Flathead Lake was homogeneous. Because of this, and due to its easy accessibility, a station near Bigfork, Montana, selected by Leathe and Graham (1981), was chosen as the sampling site for monitoring availability of kokanee food organisms.

RESULTS AND DISCUSSION

PHYSICAL LIMNOLOGY

Average water temperatures for the upper 15 m of the water column for 1980-1983 are shown in Figure 1. During April, May and June in 1983, the average temperature at the Bigfork Station was 1°C to 2.5°C warmer than in 1982 and generally less than 1°C different than temperatures for the same period in 1981. The average temperature for July and August in 1983 did not appear to fluctuate as in the three previous years. During this period, the 1983 temperature was up to 5°C cooler than in 1980 or 1981 and the 1982 minimum for this period was only about 1°C cooler than the 1983 maximum for the same period. In September and October of 1980, 1981 and 1983, the average temperature declined steadily toward 10°C. In 1982, the temperature stabilized at 12°C during this period. The maximum average temperature in 1983 was 15.8°C, compared to 17.9, 20.1 and 18.6°C in 1982, 1981 and 1980, respectively.

Thermal stratification was first noticed in mid-June 1983. A moderate thermocline remained until mid-October. Thermal stratification in 1982 was seen only from early July to late July, in

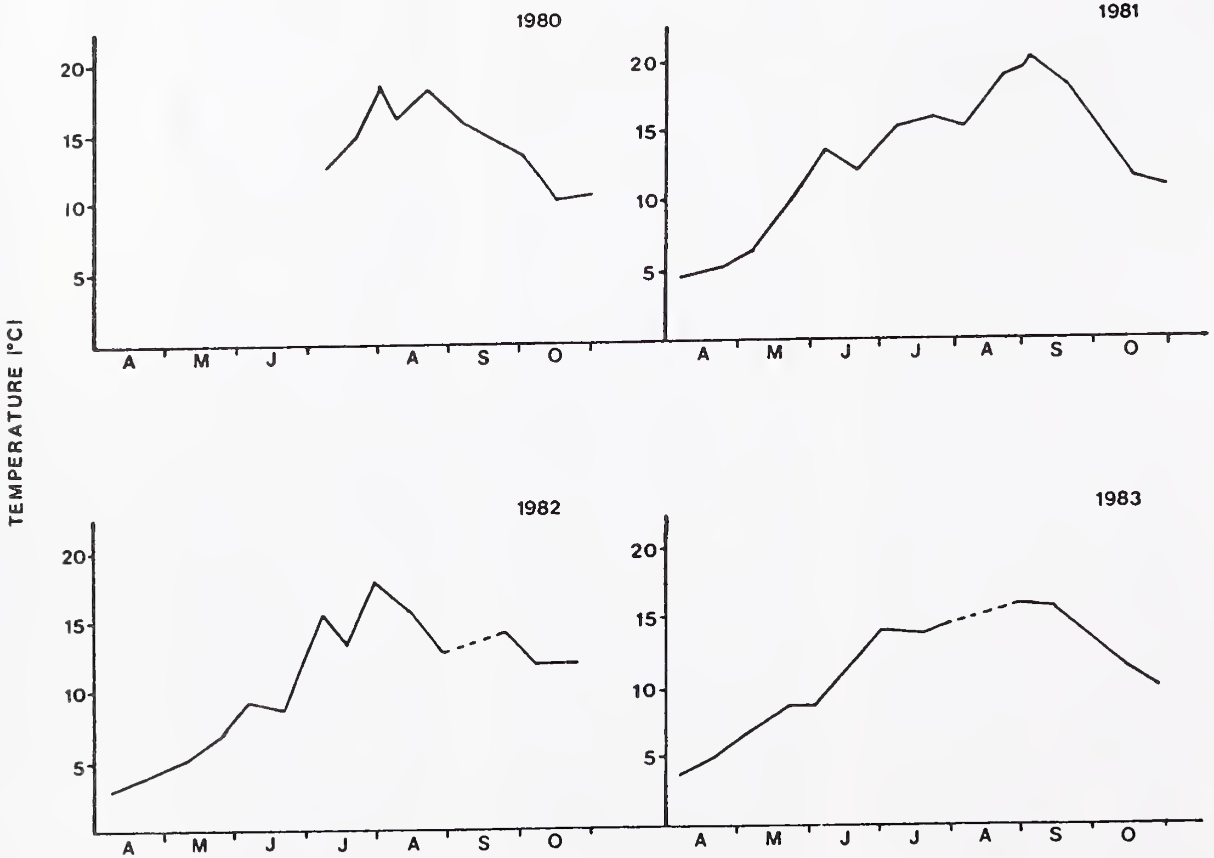

Figure 1. Mean water temperature of the surface waters (0-15m) of Flathead Lake during 1980-83.

late September, and again in mid-October. The thermocline in 1981 was present from early June through late October and in 1980 from the first sampling period in early July through late October.

Secchi disc readings for the 1983 sampling season ranged from 2.5 m to 11.0 m and averaged 7.9 m.

ZOOPLANKTON

Three copepod and four cladoceran species were collected in 1983. Copepod species sampled included Epischura nevadensis, a large plankter which is predatory on smaller species. Cyclops bicuspidatus thomasi, an omnivore, and Diaptomus ashlandi, an herbivore, were the other copepod species found. The cladoceran species consisted of Leptodora kindtii, a large predator on other zooplankton, and Daphnia thorata, Daphnia longiremis, and Bosmina longirostris, all filter feeding herbivores.

The copepods Diaptomus and Cyclops comprised an average of 77.1 percent of the total zooplankton community sampled (excluding copepod nauplii). The cladocerans D. Thorata, D. longiremis, and Bosmina composed an average of 21.9 percent of the total population. Leptodora and Epischura together accounted for less than one percent of the total. These numbers more closely approximate the composition of zooplankton found in 1980 and 1981 (Leathe and Graham 1982) than that found in 1982 (Decker-Hess and McMullin 1983) when copepod species made up 87.1 percent of the total density (Figure 2).

As in the previous three years, Diaptomus was the single most numerous organism found in the samples. It made up 60.7 percent of the total number of organisms sampled (excluding copepod nauplii) (Table 1). This is similar to the 68.5 and 54.4 percent found in 1981 and 1982, respectively, but more than the 47.2 percent found in 1980. Sampling in 1980 did not begin until July, so densities and percent compositions for that year were probably not the true values. The peak density of 26.3 Diaptomus/liter appeared in late May in 1983 (Figure 3) compared to peaks in early June the two previous years.

Cyclops comprised 16.4 percent of the organisms sampled in 1983. Three peaks occurred during the sampling year, one in late May when the density was 2.7/l, one in late August when the density was 2.8/l, and the third in late October when density again reached 2.7/l (Figure 3). Average density of Cyclops during the 1983 sampling season was 1.5/l.

Epischura made up an average of 0.28 percent of the zooplankton population in 1983. The average density during the sampling season was 23.3/m^3 (0.02/l) with the peak density of 73.0/m^3 (0.07/l) occurring in early July (Figure 3).

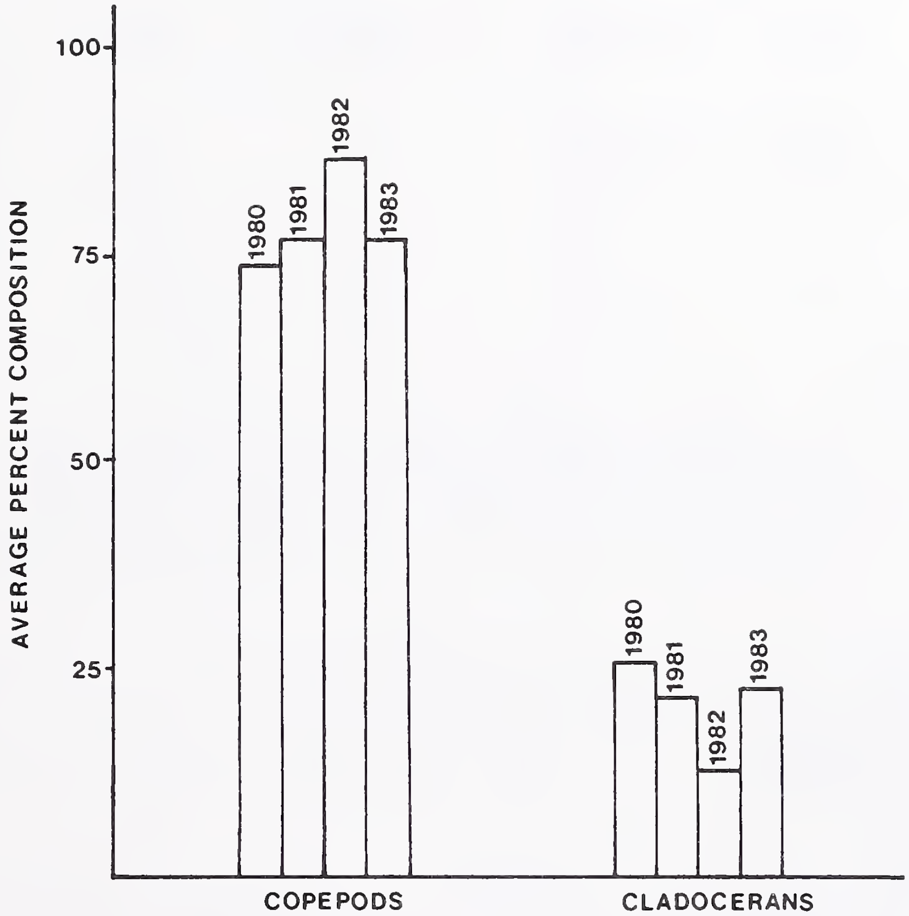

Figure 2. Comparison of zooplankton composition by percent of Cladocera and Copepod in the surface waters (0-15m) of Flathead Lake during 1980-83.

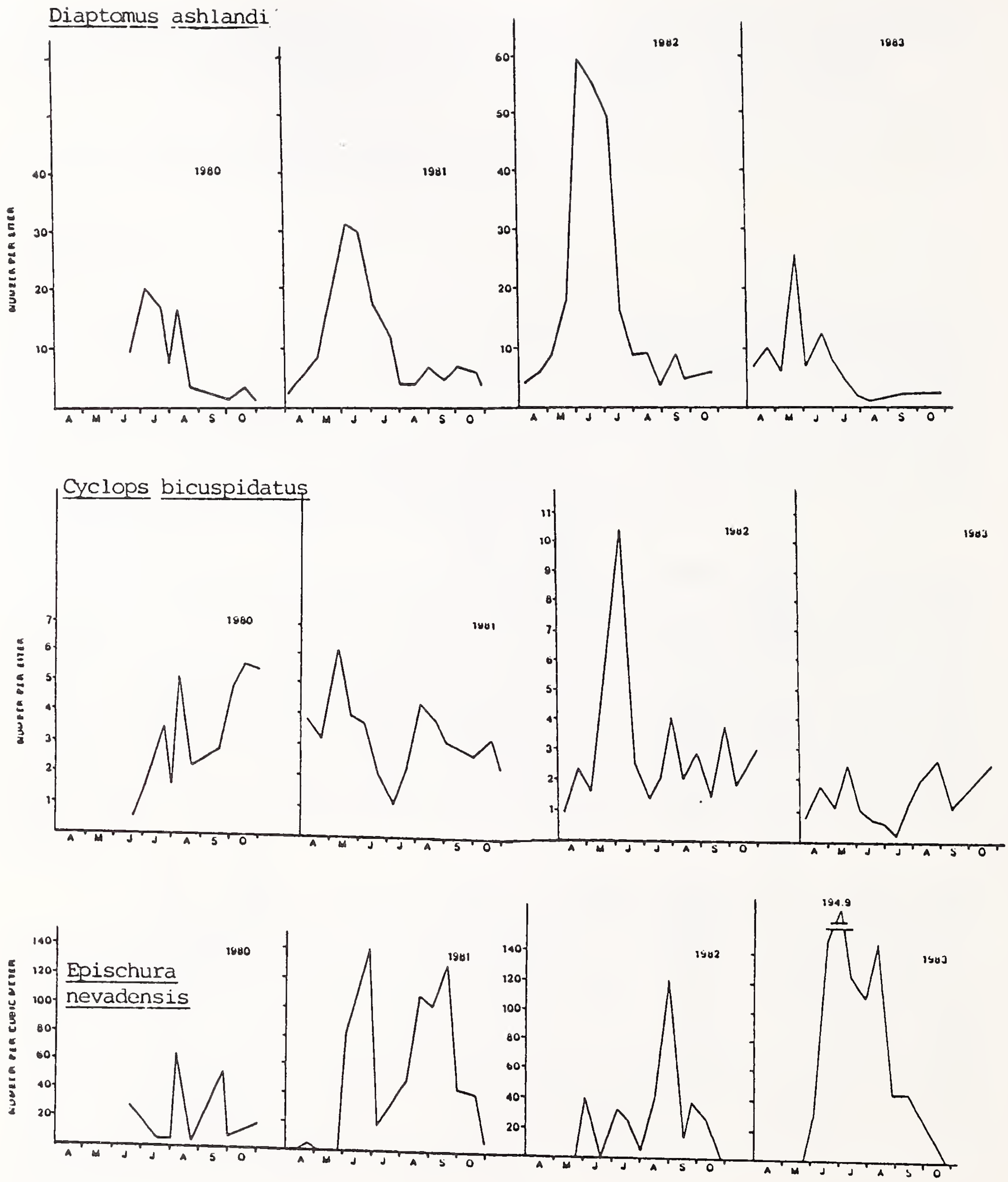

Figure 3. Seasonal density trends of copepod species in the surface waters (0-15m) of Flathead Lake during 1980-83.

Daphnia thorata was the dominant cladoceran species sampled during 1983. The average density for the season was 0.9/l with the peak of 2.1/l occurring in late August (Figure 4). *D. thorata* comprised an average of 11.5 percent of the zooplankton sampled in 1983. This percentage is similar to the percentages seen the three previous years (Table 1).

Table 1. Percent composition of the zooplankton community of Flathead Lake from 1980-1983.

	1980	1981	1982	1983
Diaptomus	47.2	54.4	68.5	60.7
Cyclops	26.6	22.8	18.6	16.4
Epischura	<1.0	<1.0	<1.0	<1.0
D. thorata	16.0	14.5	8.9	11.5
D. longiremis	4.4	<1.0	<1.0	1.8
Bosmina	5.7	7.5	3.9	8.6
Leptodora	<1.0	<1.0	<1.0	<1.0

Daphnia longiremis density in 1983 averaged 0.15/l, nearly the same as the 1982 density. The peak *D. longiremis* density was 0.38/l, seen from early August through mid-September (Figure 4). *D. longiremis* made up an average of 1.8 percent of the 1983 zooplankton population (Table 1).

Peak densities of *Bosmina* appeared at similar times in 1982 and 1983 (Figure 4). The average density in 1983 was 1.0/l with a peak of 3.15/l. However, in 1983 this species comprised an average of 8.6 percent of the zooplankton (Table 1), the highest *Bosmina* percentage seen since sampling began in 1980.

Leptodora did not appear in the samples until mid-June 1983, about one month later than in 1982, but similar to the time of initial appearance in 1980 and 1981 (Figure 4). The peak density in 1983 was 44.5/m^3 (0.04/l) in early July, with an average of 6.4/m^3 (0.06/l). *Leptodora* was the species least seen in 1983, making up 0.08 percent of the zooplankton population.

The average number of plankters in 1983 was 10.9/l (excluding copepod nauplii) compared to 18.4/l in 1981 and 23.0/l in 1982 (Table 2). Although most species showed similar percent composition of the total zooplankton population from 1980 through 1983, several important species appear to have decreased in density (Table 3).

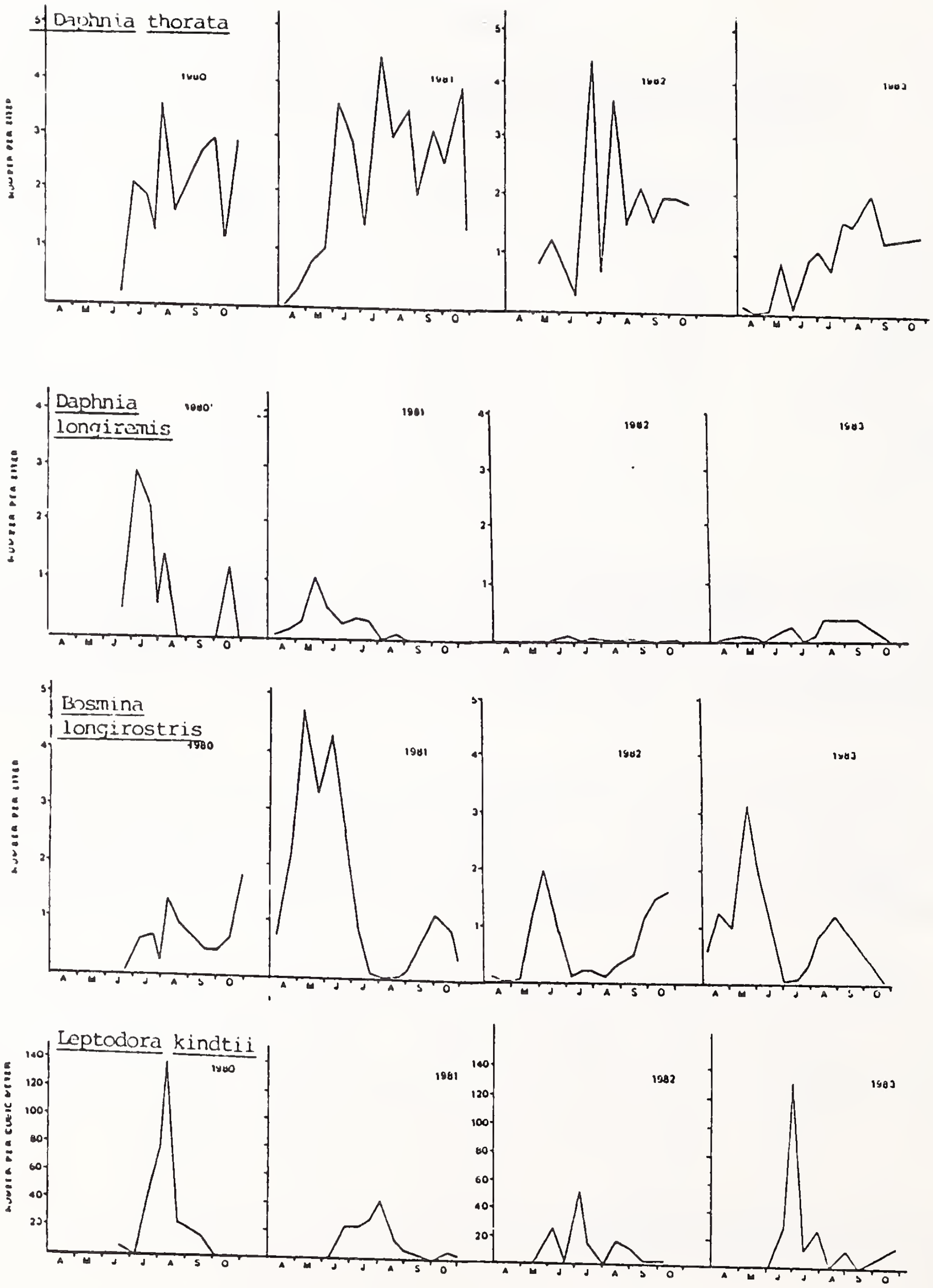

Figure 4. Seasonal density trends of cladoceran species in the surface waters (0-15m) of Flathead Lake during 1980-83.

Table 2. Average total density, peak density and date of peak density of zooplankton collected from the Bigfork Station in Flathead lake from 1980 through 1983.

	Average density (#/l)	Peak density (#/l)	Date of peak
1980*	15.2	28.4	8-7
1981	18.4	43.6	6-5
1982	23.0	73.5	6-4
1983	10.9	42.9	5-20

* sampling did not begin until July in 1980.

Table 3. Comparison of densities of zooplankton species important to kokanee for food items, 1980-1983. D. thorata and Diaptomus are expressed as number/liter and Epischura and Leptodora are expressed as number/m^3.

	1980	1981	1982	1983
D. thorata	3.2	3.4	1.5	0.9
Diaptomus	12.4	16.9	17.7	7.3
Epischura	--	34.5	39.0	25.3
Leptodora	--	7.8	14.8	7.0

Leathe and Graham (1982) found that *Daphnia thorata* was the most important food item in the diet of all kokanee size classes, comprising 70 to 90 percent of the food biomass. Age III and older kokanee used *Diaptomus* during the winter when preferred prey species were absent, and *Leptodora* and *Epischura* during the summer and fall.

Neither total zooplankton or *Diaptomus* densities changed significantly between the first full sampling season in 1981 and 1983. The densities of total zooplankton and *Diaptomus* were positively correlated ($r=0.98$ $p \leq .001$), indicating that total zooplankton density is greatly influenced by *Diaptomus* density. Comparing 1981 to 1983, *D. thorata* density did decrease significantly ($p<0.01$) and was not correlated to total zooplankton density. It is not known

whether the decrease in D. thorata density is due to the cyclic nature of the population or if some limnological or biological factors were involved. Although the density of D. thorata decreased, no temporal displacement has occurred. The first collections of D. thorata were taken during the first sampling period in April and they were present in all samples throughout the season. Kokanee fry enter Flathead Lake from the lakeshore and upstream areas from March through June (Fraley and Graham 1982 and Decker-Hess and McMullin 1983). During this period, the density of D. thorata was increasing. It was not known what effect temperature had on the zooplankton population dynamics, but it is probably similar to previous years.

The discovery of Mysis relicta in Flathead Lake in 1981 may have an affect on the zooplankton population of the lake. Mysis were captured in Flathead Lake by Department of Fish, Wildlife and Parks personnel in 1984 using a one meter diameter tow net pulled vertically through the water column (Montana Department of Fish, Wildlife and Parks, unpublished data). This is the first sampling year in which Mysis have been captured by Department personnel using this method. Rieman and Falter (1981) associated the establishment of Mysis with temporal displacement of Daphnia and Bosmina species and a change in the species composition of Daphnia present. Mysis also contributed to the disappearance of several zooplankton species from Lake Tahoe (Goldman et al. 1979; Threlkeld et al. 1980). Continued monitoring of zooplankton densities and composition and of Mysis densities in Flathead Lake will help document any changes which may occur in the zooplankton community.

LITERATURE CITED

Decker-Hess, Janet and Steve L. McMullin. 1983. Impacts of water level fluctuations on kokanee reproduction in Flathead Lake. Montana Department of Fish, Wildlife and Parks. 172 pp.

Fraley, J.J. and P.J. Graham. 1982. Impacts of Hungry Horse Dam on the fishery in the Flathead River - Final Report, USDI Bureau of Reclamation, Montana Department Fish, Wildlife and Parks, Kalispell. 91 pp.

Goldman, C.R., M.D. Morgan, S.T. Threlkeld and N. Angeli. 1979. A population dynamics analysis of the cladoceran disappearance from Lake Tahoe, California - Nevada. Limnol. Oceanogr. 24(2) :289-297.

Leathe, S.A. and P.J. Graham. 1981. Flathead Lake fish food habits study. Montana Department Fish, Wildlife and Parks, Kalispell. 93 pp.

Leathe, S.A. and P.J. Graham. 1982. Flathead Lake fish food habits study - Final Report. Montana Department of Fish, Wildlife and parks, Kalispell. 137 pp.

Rieman, B.E. and C.M. Falter. 1981. Effects of the establishment of *Mysis relicta* on the macrozooplankton of a large lake. Transactions of the American Fisheries Society. 110:613-620.

Threlkeld, S.T., J.T. Rybock, M.D. Morgan, C.L. Folt, and C.R. Goldman. 1980. The effects of an introduced invertebrate predator and food resource variation on zooplankton dynamics in an ultraoligotrophic lake. Excerpt from: Evolution and Ecology of Zooplankton Communities. Special Symposium Vol. 3. American Society of Limnology and Oceanography. W. Charles Kerfoot, Ed. University Press of New England. Hanover, N.H. and London, England. 1980.

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